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USE OF MAMMALIAN SKULLS AND MANDIBLES BY PREHISTORIC INDIANS OF ILLINOIS

PAUL W. PARMALEE
Illinois State Museum, Springfield

Prehistoric Indians that once occupied the eastern United States subsisted almost entirely upon game which inhabited areas where their camps and villages were located. Although certain wild plants provided some food, as well as cultivated crops grown by later cultural groups, the bulk of the diet of aboriginal Illinois Indians consisted of native mollusks, fishes, turtles, birds and mammals. Especially in the case of the latter two, many of the bones were worked and fashioned into a variety of ornaments, tools and utensils.

In most instances it appears that such bone artifacts represent a secondary use of the animal, the primary use having been as food. However, worked mandibles and maxillae of the black bear and gray wolf, for example, have been found in association with human burials, primarily those of the Hopewell culture, while their other remains are almost entirely wanting in village midden deposits and refuse pits. These often elaborately cut and drilled sections of maxillae and mandibles were of special significance—possibly religious, a symbol of bravery, or simply as an ornament or trophy.

This type of bone artifact has been found in association with all three major prehistoric cultural groups (Archaic; Woodland; Mississippian) in Illinois, but apparently only during the Hopewell phase of the Woodland Culture were there any "extensive" manufacture and use of these bone ornaments. The only thoroughly excavated Archaic site in the state is the Modoc Rock Shelter Site (Fowler, Winters, and Parmalee, 1956) located in southwestern Illinois. Although no extensively worked or drilled mandibles or maxillae were found, a right mandible of a bobcat was recovered that had apparently been cut at the symphysis (separating it from the left half) and handled or worn a great deal as evidenced by its smoothed and polished appearance.

Mayer-Oakes (1955: 209, Fig. 19-1) has illustrated a "Cut, polished and perforated bear jaw" from the Archaic East Steubenville Site in Ohio; generally, such bone artifacts are uncommon in Archaic sites. However, some unique artifacts have been reported from the Archaic Indian Knoll Site in Kentucky. A section of the skull (rostrum) and mandible of a bobcat were found with three burials, while two cut mandibles of the gray wolf and four mandibles (plus the rostrum) of the fisher, *Martes pennanti*, occurred with others (Webb, 1946: 228, Fig. 30). These are of special interest since they were associated with a preceramic culture. The use of cut mandibles and maxillae for decorative and/or ceremonial (?) purposes, primarily those of the larger carnivores and mustelids, apparently decreased with the decline of the Hopewell culture. They are

known from the later Mississippian groups, but are uncommon and do not exhibit the workmanship of the cut and perforated bones of the Hopewell period.

Canine teeth, mostly from smaller carnivores such as raccoon and fox, and typically perforated at the root end for suspension, have been found in varying numbers at several Illinois sites. Deuel (1952b) refers to 179 perforated canine teeth of the raccoon that "lay in the neck region of a skeleton of a middle-aged person in Baehr Mound 2 (Brown County)." He also noted more than 200 drilled incisors of squirrels, that occurred with a skeleton in the Hemphill Mound in Brown County. The incisors of beavers were often used as a tool, possibly some type of chisel; more have been found at the Fisher Site (Will County) than in any other Illinois site.

The following accounts deal with the species of mammals utilized by the prehistoric Indians of Illinois for the manufacture of jaw and skull ornaments, pendants and utensils. These data provide an index to cultural traits, to the use and possible significance of certain species to the Indian and to the former abundance and distribution of these animals. Figure 1 illustrates several typical cut mandibles and maxillae which have been recovered at various archaeological sites in Illinois.

Accounts of Species

BLACK BEAR, *Ursus americanus* Pallas.—Now extinct in Illinois, the black bear was fairly common in wooded sections in early times. As noted previously, remains are rare in refuse pits and midden debris of prehistoric sites in Illinois and apparently only historic tribes used the bear for food, and possibly for robes and clothing. To the prehistoric Indian (primarily Hopewell) the bear appears to have had special significance and apparently was killed principally for the canine teeth, mandibles and skull.

Illustrations and discussions in the literature dealing with the bear's canine tooth and its use as a pendant or necklace component are too numerous to list. These teeth were a favorite with the aborigines; some were split, often drilled (one to several holes) and occasionally inlaid with pearls. The manufacture of imitation bear's teeth by the Indian is especially noteworthy since it also infers that the bear had special significance. Such canine teeth, made from bone, occurred in the Wilson Site Cemetery (Wh°10), White County (Deuel, 1952a) while two similar shell "teeth", fashioned from the axis of a marine whelk, were found with a burial in the Morton Mound F°14 in Fulton County (Cole and Deuel, 1937); these carved shells had apparently been worn as ear pendants.

Several imitation bear's teeth made from sheet copper have been recovered in mounds of the Liverpool group in Fulton County. Five of these (Dickson Mounds State Park Museum near Lewistown) were found lying on the skull of a burial, apparently having been worn as a head band. Each was approximately three and one-half inches long and contained two, centrally drilled holes. Four imitation canines were found at the Weaver Site, Ful-

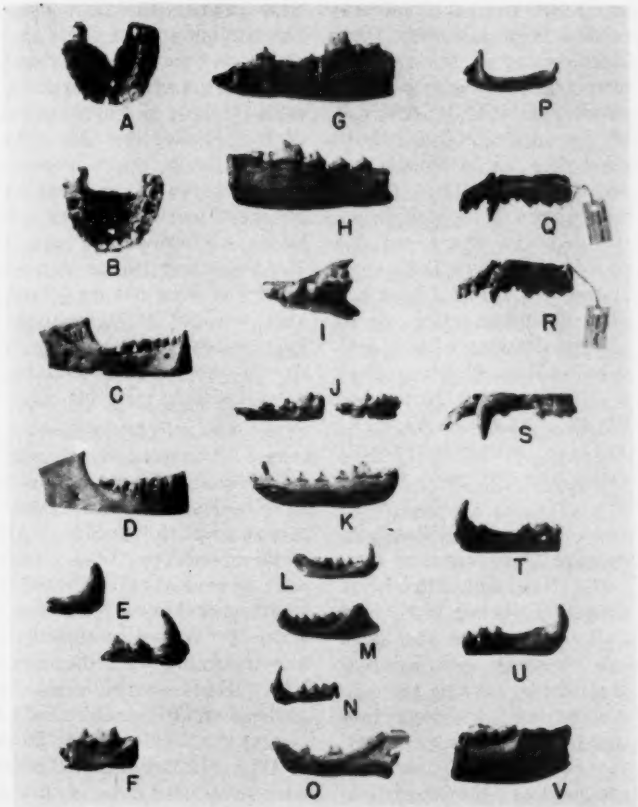

FIG. 1.—Types of cut mandibles and maxillae from archaeological sites in Illinois. *A* and *B*, palatine sections of human skull, Liverpool mounds, Fulton County; *C* and *D*, human mandibles, Sister Creeks Site, Fulton County; *E*, mountain lion mandibles, Mound F°191, Fulton County; *F*, mountain lion mandible, Little Chains Site, White County; *G* and *H*, mandibles of gray wolf and *I*, maxilla of gray wolf, Clear Lake Site, Tazewell County; *J*, maxillae of domestic dog, Clear Lake Site; *K*, coyote mandible, Cahokia Site, Madison County; *L* and *M*, badger mandibles, Clear Lake Site; *N*, bobcat mandible, Jersey County, Mound 69; *O*, bobcat mandible, Modoc Site, Randolph County; *P*, raccoon mandible, Snyders Site, Calhoun County; *Q* and *R*, black bear maxillae, Dickison Mounds, Peoria County; *S*, black bear maxilla, Mound Wh°6, White County; *T* and *U*, black bear mandibles, Liverpool mound; *V*, black bear mandible, Clear Lake Site.

ton County (Wray Coll., I.S.M.); two with a male human burial in a Hopewell cemetery and two in a house pit in the village. These ear pendants had been made by overlaying sheet copper on wood carved in the shape of a canine; portions of the wood were stilled preserved.

One of the most unique artifacts encountered thus far in Illinois was found in a "log tomb" mound (Hopewell) of the Liverpool group. A piece of bone had been cut and ground to resemble a handled dagger while the canine tooth of a bear had been hollowed out to serve as its sheath. A line drawing of this artifact (Dickson Mounds State Park Museum) is shown by Moorehead (1928: Pl. 49). Although he refers to it as that of a "grizzly bear tusk", it is probably the canine of a large black bear.

Cut and drilled maxillae and mandibles have been found in association with Hopewell burials in Illinois, maxillae being the more common. Bone artifacts fashioned from skulls generally included that portion obtained by cutting through the roots of the teeth and longitudinally through the palatine section; typically, each contained three incisors (premaxilla), the single canine, the premolars, and the first molar. Four such artifacts (two bears) from the Dickison Mounds in Peoria County are mistakenly illustrated as "halves of wolf mandible" (Deuel, 1952a.: Pl. 8, Figs. A and D). Three others occurred in the Wilson Mound Wh°6 and two in Mound Wh°7, White County (Deuel, 1952a: Pl. 67, Figs. D and G, and Pl. 72, Fig. C).

Two cut and drilled bear mandibles (same individual) were recovered with a human burial in a Liverpool mound (Dickson Mounds State Park Museum). They were cut similar to the skull types and, although the incisor teeth were missing, the original artifact apparently include the apex of the mandible. Evidently, the only other artifact made from a black bear jaw and found in Illinois was recovered at the Clear Lake Site, Tazewell County, (Schoenbeck coll., I.S.M.). The ascending ramus of a left mandible had been cut away and it had also been cut at right angles to its longitudinal axis, leaving only the second and third molars intact (Deuel, 1952a.: Pl. 50, Fig. O).

RACCOON, *Procyon lotor* (Linnaeus).—The quantity of raccoon remains found in numerous Illinois sites indicates extensive use of the raccoon by the Indian. Although certain bones (*e.g.* the ulna, radius and os penis) of the raccoon were modified and used as awls or other tools, the animal was probably collected primarily for its flesh and/or hide. Mr. Gregory Perino found a worked right mandible of a raccoon at the Snyders Site (Hopewell) in 1955 (I.S.M. coll.). The ventral side was ground flat and then several shallow grooves were cut in this surface at right angles to its longitudinal axis.

The only other Illinois record of a worked raccoon mandible is one described and illustrated by Maxwell (1951: Pl. 5) from the Sugar Camp Hill Site, Williamson County. He decribes it as "cut through the ramus, polished and scratched deeply with a knife along the labial wall". However, this description

does not fit his illustration and, according to Maxwell (pers. comm.), this was the preliminary field description of a specimen later classified as unworked. Maxwell (*op cit.*: 106) also states that "a lynx mandible was cut in back of the canine and gouged with three wide shallow incisions on the labial side at right angles to the longitudinal axis of the mandibles and drilled into, but not through the bone in two places on the lingual side"; this description applies rather to the illustrated raccoon jaw.

WOLVERINE, *Gulo luscus* (Linnaeus).—The presence of two cut and perforated sections of mandibles of this species in Mound No. 6 of the Havana Mound Group (Mason County) represents a unique record since there are no historic accounts of the wolverine in Illinois. These artifacts were described and figured as parts of a dog's jaw (Baker, 1941: 11, 69 and Pl. 7) but were later determined as *G. luscus* by Hoffmeister (1954) who states "Indians in Illinois probably obtained these bone artifacts only by trading with Indians far to the north or by hunting far to the north of the present boundaries of Illinois."

RIVER OTTER, *Lutra canadensis* (Schreber).—This mustelid was not uncommon in Illinois in early times but the limited number of otter bones at most sites indicates it was taken only occasionally by the Indian. There are apparently only three instances in which otter remains were used for ornaments or decoration. Mr. Perino recovered the cut palatine section of an otter skull in a Hopewell mound (No. 4 near Bedford, Pike County); this skull section contained the full complement of teeth. Langford (1927: Pl. 21, Fig. F) records a nearly complete skull and left mandible from the Fisher Site; it was described in his original notes as having been found "on a woman's forehead in the Middle Level of the Big East Mound EM". Originally the skull may have been worn (with the hide?) in the form of a headdress.

Mr. Theodore Shapas, Dolton, found the anterior half of a skull and the complete right dentary of *L. canadensis* with a human burial at the Anker Site, an Upper Mississippi Site at South Holland, Cook County. This find was noteworthy since the skull had been wrapped in sheet copper and copper disks had been placed in the eye sockets.

BADGER, *Taxidea taxus* (Schreber).—The badger is uncommon in Illinois although earlier it was reported as numerous, at least in the northern third of the state. Its bones have been identified from only five Illinois sites and, except for the complete skeleton (apparently interred by the Indians) found in Rose Mound No. 13, Schuyler County (Baker, 1941), they were few in number at each site. Three mandibles, a maxilla section and the anterior half of the skull were recovered at the Clear Lake Site (Schoenbeck coll., I.S.M.); two of the mandibles had been worked. The ascending ramus of one had been cut off at the mandibular foramen, but the other had been more elaborately worked (Deuel, 1952a: Pl. 51, Fig. I) with both the ventral side and most of the ascending ramus cut off and noticeable scratch marks on both lateral surfaces. It appeared polished, pos-

sibly from being handled; neither mandible had been perforated.

GRAY FOX, *Urocyon cinereoargenteus* (Schreber).—The only record of a fox mandible worked by the Indian occurred at the Pool Site, Pike County. Found in 1950 (Univ. Ill., Dept. Sociol. and Anthrop. coll.), the section of a right mandible had been worked to a limited extent; the ventral margin was ground to a flattened surface and the condyloid process was cut off. None of the teeth remained and it had been broken off between the carnassial and second molar. Possibly this slightly altered jaw was in the initial stages of manufacture and originally it probably included more of the mandible.

DOMESTIC DOG, *Canis familiaris* Linnaeus.—Remains of the domestic dog have been found in midden deposits of all cultural groups, from the Archaic to those of historic tribes. Bones of the dog were seldom modified for tools or ornaments by the Indian, although there are records from a few Illinois sites of cut limb bones of *Canis* and of ulnae fashioned into awls. The only skull or mandible artifacts that are probably referable to the domestic dog were recovered at the Clear Lake and Cahokia sites. At the former site, two sections of the right maxilla were found in the village debris. Although the anterior portions of both had been broken off and lost, it was evident that one had been cut off immediately posterior to the carnassial tooth while the other had been cut behind the last molar. The artifacts were not drilled and their use is a matter of speculation.

Mr. Perino found a section of a worked canid mandible in Mound No. 34 at the Cahokia Site, Madison County. The ascending ramus was cut off immediately behind the third molar and the ventral edge was ground down close to the base of the teeth; the mandible was broken where the carnassial tooth was originally located. Specific identification is uncertain since only the second molar remained, but this tooth and jaw section compares most closely with *C. familiaris*.

COYOTE, *Canis latrans* Say.— As evidenced by the scarcity of remains of this animal in Illinois sites, the coyote was rarely taken by the Indian. Two badly decomposed cut mandibles were found at the Kraske Site, St. Clair County, in 1957 by Mr. Perino and are probably *C. latrans*. He also recovered a section of a right mandible of the coyote at the Cahokia Site in 1956. This artifact bears scratch marks on both lateral surfaces and the proximal end had been cut off between the second and third molars and rounded along the ventral margin. It is noteworthy because this carefully worked jaw was recovered at a Middle Mississippi site.

McGregor (1958) reports a cut canid mandible with a burial at the Pool Site, Pike County. The ventral edge was cut off parallel to the long axis of the jaw and the posterior section had been removed by cutting through the mandible at the position of the carnassial tooth, leaving only the anterior one-third of the tooth. The anterior portion of the artifact originally included more of the mandible; it had been drilled just below premolars two and four. Specific determination

was difficult, but based on cusp structure, tooth dimensions and the general narrowness of the jaw, it compared most closely with coyote rather than dog or wolf as proposed by McGregor (1958: 139, 141, Fig. 46,f).

GRAY WOLF, *Canis lupus* (Linnaeus).—This large carnivore was reported to have been fairly common in the wooded sections of Illinois prior to 1800, but it has long been extinct in this region. Bones of the gray wolf have been reported from only nine Illinois sites and it was evidently seldom killed by the Indian. Artifacts fashioned from the bones of this species suggest it may have been sought more as a trophy animal than as a source of food. An ulna, apparently used as an awl, and the cut distal end of a humerus occurred at the Weaver Site, Fulton County (Wray coll., I.S.M.).

Two cut mandibles and a section of maxilla, probably the same individual, were recovered at the Clear Lake Site (Schoenbeck coll., I.S.M.). None of the artifacts were perforated; each had been cut through at the point of the canine tooth and the ascending ramus cut off, but all of the premolar and molar teeth were left intact. Another section of maxilla, probably of *C. lupus*, was also recovered at the Clear Lake Site (Wray coll., I.S.M.). Posteriorly, it had been cut through the middle of premolar three and, although only this and premolar two remained, the artifact originally was more extensive.

The maxillae of a wolf were recovered in 1956 by Mr. Perino at the Cahokia Site; although weathered and broken, these pieces bore evidence of having been cut. Maxwell (1951: Pl. 5) illustrates the worked jaws of this species recovered at the Sugar Camp Hill Site, Williamson County, and states "Also in Zone II were two sections of the right and left sides of a wolf mandible, flattened on the bottom, cut in back of the carnassial and perforated in six places". Langford (1927) refers to "two carved bear jaws" he recovered at the Fisher Site, although judging from the plates (17, e; 20), these (premaxillae-maxillae) appear to be a large canid, possibly wolf. Langford (*op cit.*: Pl. 17, d) illustrates and mentions a "part jaw (of canid?) showing chopping marks" that may also be *C. lupus*.

The cut right mandible of *C. lupus* was found at the Busch Estate Site (Woodland), Pike County (Univ. Ill. Dept. Sociol. and Anthrop. coll.). The unperforated mandible contained the third and fourth premolars and the anterior portion of the carnassial; it was cut off anteriorly at the second premolar and the ventral edge had been cut off parallel to the long axis of the jaw.

In 1957, Mr. Theodore Shapas, Dolton, recovered portions of two left mandibles of the gray wolf with a human burial at the Anker Site, Cook County. One mandible contained premolar four, the carnassial tooth and molar two, while all three molars and premolars two and three were still present in the other. These mandibles had been broken but were not cut or drilled, although they definitely had been part of the burial complex. On October 18, 1958, at the same Upper Mississippi site, Mr. Shapas found a cache of jaw

and skull remains above the pelvis of a burial; these may have been contained in a pouch of some sort. Except for the missing rami and the purposely (?) broken ventral margins, the lower mandible of this large wolf was complete. Also included was a single canine, the right premaxilla containing three incisors and canine tooth and both right and left maxilla sections, each with premolars three and four and both molars intact (probably all from the same wolf). Portions of the right maxilla and both mandibles of a bobcat formed part of the cache; these remains were not worked.

At this same site, Mr. David Pedric, Dolton, found two larger, nearly complete mandibles of *C. lupus* with a burial. The ascending rami were broken off and each, which still contained a full complement of teeth, had been drilled in two places at mid-point between the gum line and ventral edge, one below the third premolar and one below the carnassial.

There are apparently only two instances known in Illinois in which the skull of *C. lupus* was elaborately modified to form an artifact. A field party from the Department of Anthropology, University of Michigan, Ann Arbor, recovered a broken section of the right premaxilla-maxilla (Cat. No. 9829) of a wolf at the Snyders Site (Hopewell), Calhoun County, in 1947. It was broken behind the first premolar; only the three incisors and broken portions of the canine tooth and first premolar remained. The palatine section and upper part of the maxillary had been cut away and a hole drilled between the canine tooth and the third incisor; originally the complete artifact probably contained another drilled hole, posteriorly.

During the excavation of a burial in Mound 2 several years ago, at the Knight Site (Hopewell), Calhoun County, two unperforated premaxilla-maxilla sections of the gray wolf were recovered by Dr. P. F. Titterington, St. Louis (U. Mich. Cat. No. 44779). They were cut off immediately posterior to the second premolar and the maxillary had been cut away parallel to the gum line, exposing the roots of the teeth. All the incisors, canines and first and second premolars were intact.

MOUNTAIN LION, *Felis concolor* Linnaeus.—The comparatively few animals that once inhabited this region, coupled with the probable difficulty encountered by the Indian in killing the mountain lion, may account for the scarcity of its remains at sites. An unworked section of the pelvis occurred at the Starved Rock Site (LaSalle County), and the distal end of a tibia of this species was recovered in the village debris at the Rosiclare Site, Hardin County (I.S.M. coll.). An awl made from the ulna of this cat was found with a human burial by Mr. David Pedric at the Anker Site.

In Mound F°191 (Mitchell Mound), Fulton County, the cut anterior section of a right mandible that contained the canine tooth and both premolars was found by Dr. Don Dickson and mistakenly referred to in Cole and Deuel (1937) as "a wolf jaw". The fragment of a left mandible containing only the canine tooth (probably the same animal) was also recovered. Two cut and perforated mandibles of the

mountain lion (same animal, originally with the full complement of teeth) were found with a Hopewell burial in Mound Wh°7, White County, and are illustrated (Deuel, 1952a: Pl. 72, Fig. E) but mistakenly identified as "cut wolf jaws . . . ." The only other record is a broken section of left mandible (containing the molar tooth and premolar two) found by the author in July, 1956, at the Little Chains Site, White County. The ascending ramus had been cut off just posterior to the molar tooth.

BOBCAT, *Lynx rufus* (Schreber).—With reference to historic tribes in southeastern United States, Swanton (1946) mentions that "The wildcat seems to have been eaten at times and its skin was also worn". Faunal remains indicate that this cat was used to some extent by the aborigines, although artifacts fashioned from the bones of *L. rufus* are uncommon in Illinois sites. Titterington (1942) lists the "cut section of fox mandible, Burial No. 49—Mound 69", from the bluff focus in Jersey County, but this mandible is that of a bobcat. The right mandible of *L. rufus* recovered at the Modoc Rock Shelter (mentioned earlier in this paper) is the only artifact of its type known from an Archaic site in Illinois. The complete dentary and anterior two-thirds of a skull of a large bobcat were found on the chest of a human burial by Mr. Pedric at the Anker Site. Like the otter skull recovered at this site, the skull of *L. rufus* had been wrapped in copper and copper disks inserted in the eye sockets.

WHITETAIL DEER, *Odocoileus virginianus* (Zimmermann).—An almost limitless variety of artifacts fashioned from nearly all of the different bones of this animal have been found, but ornaments and pendants made from the skull or mandible are rare. However, there are records (*e. g.* Perino, 1957: Fig. 49) of complete mandibles which were used probably as some sort of grubbing or cultivating tool.

Four cut mandibles have been recovered from Illinois sites thus far. Maxwell (1951: Pl. 5) records a "cut and polished section of deer mandible" from the Sugar Camp Hill Site. A cut portion of the right mandible occurred with a burial at the Irving Site (late Middle Woodland), Pike County (McGregor, 1958: 150, Fig. 51 B). The ventral edge had been cut off parallel to the long axis of the jaw; the ascending ramus was removed by making a cut that began part way up on the anterior edge of the ramus and curved down to join the ventral cut. The artifact was broken and only the second and third molars remained; originally it probably included more of the dentary. The broken, worked section of a right deer mandible occurred at the Pool Site (Hopewell), Pike County (Univ. Ill., Dept. Sociol. and Anthrop. coll.). Again, the ventral edge was cut away and the anterior section had been removed by cutting immediately in front of the first premolar. Only broken portions of premolars one and two remained, although originally the artifact included the third premolar and at least the first molar.

A broken section of a left mandible was recovered by Mr. Raymond Bieri, Belleville, in a refuse pit at a Late Woodland site near Falling

Springs, Madison County. The ventral edge had been cut away and both lateral surfaces bore distinct scratch marks; although this artifact had originally included more of the mandible, only premolar three and the first molar remained. Deuel (1952b) states that "One of the most interesting finds from the Liverpool group (Mound 77?) consists of two antlers of a young Virginia buck found near the head of a skeleton and doubtless part of a headdress". This is apparently the only case noted from Illinois of complete deer antlers being used in this type of an ornamental or a decorative capacity.

MAN, *Homo sapiens* Linnaeus.—The use of human skulls and mandibles as ornaments and pendants appears to have been restricted in Illinois to the Hopewellian culture, and nearly all such artifacts have been found with human burials in Fulton County mounds (Sister Creeks and Liverpool sites). Typically, the mandibles were separated at the symphysis, the ventral surface was cut away along an even line, the ascending ramus was cut off half way to the coronoid process and each was perforated for suspension. The palatine section was kept (with the full complement of teeth) and, like the mandibles, was also drilled for suspension. Several of these human bone artifacts in the archaeological collections of the Illinois State Museum are illustrated (Cole and Deuel, 1937: Pl. 23, Fig A; Pl. 26, Fig. B; Pl. 31, Fig. B); similar specimens from Hopewellian mounds are on exhibit at the Dickson Mounds State Park.

Interesting hypotheses have been proposed by Deuel (1952b). "Since bear and wolf jaws were worn, it would seem that the more powerful fighting wild animals were chosen and hence, that the human mandibles and maxillaries were those of brave enemies and worn for a like reason. However, if the jaws had a protective quality or religious significance, they might rather represent friendly relationships and hence the human jaws might be those of dead friends, patrons or relatives."

Summary

Worked mandibles and/or maxillae of 13 species of mammals have been recovered from archaeological sites in Illinois. Although these bone artifacts occurred in Archaic and Mississippian sites, they have been encountered most frequently in Hopewell burial mounds. With respect to this latter cultural group, the mandibles and skull sections are more meticulously cut and polished and, in nearly every instance, perforated for suspension. The scarcity of bones of the black bear in the village midden debris of prehistoric sites in Illinois indicates that the animal was killed primarily for its skull, mandibles and canine teeth.

Acknowledgments

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ARTIFICIAL GROUND WATER RECHARGE AT PEORIA, ILLINOIS

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In Peoria, Illinois, ground water is obtained from glacial drift deposits varying from 10 to 200 feet in depth. In addition to municipal use, most industries also pump this water. In 1940 it was found by the State Water Survey that ground-water levels were dropping about two feet per year and that the cause was over-pumpage. It was also found that the river does not contribute to the ground-water storage when it is at pool level and only very little when in flood stages.

To reduce lowering of ground-water levels, two principles can be used: a) pump less water; or b) increase the recharge of ground-water storage. Both methods have been used. Once informed about the causes of the lowering, industry cooperated by reducing its pumpage to the extent of 15 million gallons per day mainly by using river water for condensers or by building cooling towers. These measures reduced the recession of water tables to about 0.6 foot per year.

A trial of artificial recharge was made in 1941 in an old gravel pit on the property of Hiram Walker & Sons, and it was found that recharge could be made at a rate corresponding to the height of a water column of 111 feet per day over the water surface or at rate of 37 million gallons per day per acre.

Artificial recharge can be obtained in several ways. In Peoria we studied the use of land flooding, pits, and wells.

Land-flooding, as a rule, gives rates of inflow from a few inches to a maximum of five feet. Inasmuch as in Peoria the over-pumpage was calculated to be 8 to 10 million gallons per day we would need 30 acres to flood if the rate of inflow averaged one foot per day. This amount of free land was not available in the industrial area where the recharge was needed.

It was, therefore, considered necessary to find a method which allowed a high rate of recharge over a small area. Wells or pits can be used for this purpose. Wells require clean water or they clog and are difficult to put back in operation. The cost of a filter plant and recharge wells was estimated to be about $5 million whereas the cost of a pit was approximately $100,000. From this standpoint it was not difficult to choose.

The quality of the river water was found to be satisfactory for infiltration; it had a turbidity of less than 100 p.p.m. for 300 days per year and a normal bacterial count of 26,000 per ml. However, convincing people locally that river water can be used for recharge required much time and effort.

The State of Illinois appropriated funds that would have allowed the construction of a small recharge test-pit with a capacity of about

300,000 gallons per day. The Peoria industries, being interested in getting even more water into the ground, raised an additional $70,000 to enable construction of a larger pit having a possible capacity of one million gallons per day over the year, that is, two million gallons per day over the approximate six-month operating period. The pit is operated only during the winter period when the river water is below 65°F. The contribution from the industries, fortunately, was made with a free rein for research, and there was never any pressure exercised merely to get more water into the ground. The water committee of the Peoria Association of Commerce always considered the work as a research project designed and operated to find ways to solve the problem of rapid recharge.

Description

The installation is relatively simple. River water passes through a coarse screen to a so-called control tower, where it is chlorinated, measured, and passed through fine screens with ⅛-inch slots. It then enters the pit which has its bottom 10 feet below pool stage of the river and thus is charged by gravity flow. To protect the natural ground from settling the pit was lined with a six-inch layer of filtering material.

In 1956 a second recharge pit, with some modifications in shape, was built near the first one. The water is pumped into this no. 2 pit.

Whereas pit 1 has a bottom 40 by 62.5 feet (2500 sq. ft.) with 1:2 slopes, pit no. 2 has a bottom of 20 by 75 feet (1500 sq. ft.) with 1:3 slopes.

Industrial Pits

The pit belonging to the Bemis Brothers Bag Company in Peoria, which has a bottom only 10 by 50 feet and slopes of 1:3, was built with advice of the Water Survey.

In contrast the Peoria Water Works Company built a pit with a bottom 350 by 200 feet and 1:3 slopes with a six-inch layer of sand as filter.

There are in Peoria, therefore, four pits of various shapes available for observation and comparative study.

Rates of Inflow

It is interesting to compare the average rates of inflow in feet per day in these pits.

Pit 1	60
Pit 2	120
Bemis Bag Co. pit	200
Water Works Co. pit	8

The Peoria Water Works Company pit approaches land-flooding types of recharge in size and recharge rate.

The high recharge rate of the other pits, however, is surpising and exceeds the rate of any known pit. The reasons for this high rate are well worth discussing, as the design of many pits seems to overlook some fundamental reasoning.

Design Factors

In any recharge pit, the water level in the pit must be above the original ground-water level in order to have some head to produce flow. The volume of soil between the pit and the ground water is soon saturated with water. In Peoria we calculate that this happens in three hours.

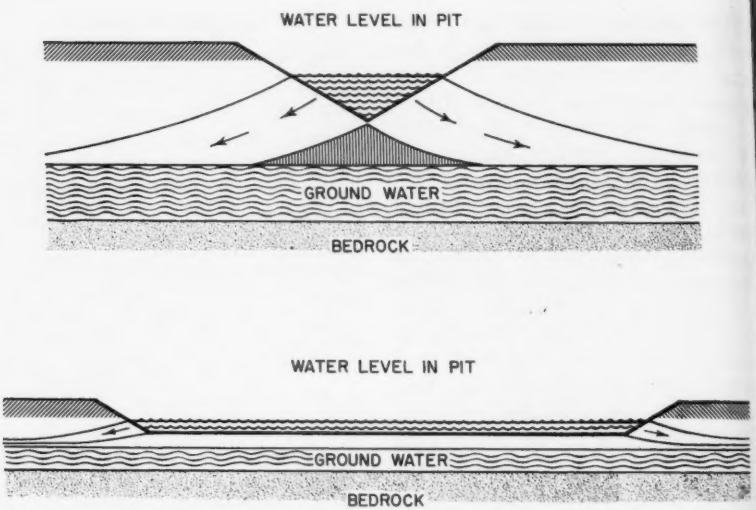

FIG. 1.—Sections through pits and flow diagram; *above*, Pit without bottom, only slopes; *below*, Pit with large bottom.

Any additional water can flow from the pit only if it can flow from the pit laterally. The water flowing through the sides of the pit has a free direct path for this lateral flow. The water flowing through the bottom has to squeeze through underneath the flow from the sides, and in large bottoms the flow from one part of the bottom can block or hold back flow from another part. It thus becomes evident that large bottoms are of no great help in increasing the rate of inflow.

Assuming a pit without a bottom (Fig. 1, above), there is flow only through the sides, and beneath its lowest point is a sector with no flow, as stream lines cannot cross themself.

In a pit with a very large bottom (Fig. 1, below), it can be seen that a limited lateral flow is possible only through a section along the edge of the bottom. In large pits this may be less than could flow through the bottom due to its permeability. This accounts for the low rate of inflow in land-flooding operations.

The geometrical shape of the pit is therefore of great importance in obtaining a high rate of inflow.

It was also found that a high percentage of the wet area should be in the slopes (Fig. 2). At operating levels in the pits in Peoria, this area amounts to:

Pit 1	55 percent
Pit 2	75
Bemis Bag Co.	90
Water Works Co.	20

FILTER MATERIAL

Another rather unexpected factor in obtaining and maintaining high rates of infiltration was the filter material.

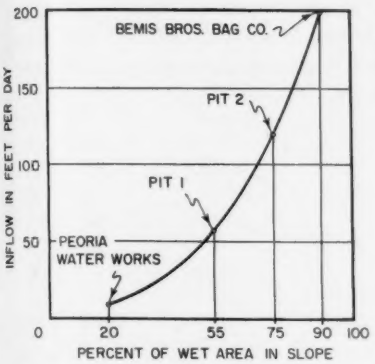

FIG. 2.—Relation between inflow and percent of wet area in slope.

For the first three years sand of one-millimeter size was used for filtering. This sand clogged rapidly and at the end of a winter season the capacity of the pit was reduced 40 to 60%. Then, in a bold step, 3/8-inch gravel was used as filter material. This material was predicted as not being capable of acting as a filter, but in our testing it proved effective.

A silt film developed rapidly over the gravel and the top gravel collected more silt than the lower layers. At the end of the season practically all of the silt introduced into the pit by the river water could be accounted for in the top layer of gravel. What was even more important, the initial inflow was about 5% higher than with sand as a filter and the reduction during a winter season amounted to only 12 to 15%. This solved to a great extent the constancy of the pit operation.

During 1957-58 pits nos. 1 and 2 were operated without previous cleaning. So far the loss in the recharge rate is only 4% compared to the previous year. This low loss of capacity suggests that operation of the pits may be possible three years without cleaning.

It is our opinion that use of pea gravel as a filtering material, geometric shape of the pit, and flow through the sides are the main factors in the high rate of recharge of the pits in Peoria. However, many other factors also enter the problem of ground-water recharge.

CONCLUSIONS

Technically, we found a way to produce a high rate of recharge of water into the earth. On the other hand we do not yet know why many of the methods work. We do not know the most favorable geometric shape for a pit or the proportions of sides, bottom, and slopes. We do not know why pea gravel actually filters or the limit of coarseness of material that could be used. However, theoretical and experimental studies on these explanations are underway.

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EIMERIA (PROTOZOA: EIMERIIDAE) FROM THE RICE RAT AND PYGMY MOUSE IN MEXICO

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Materials and Methods

During the summer of 1958 a collecting expedition to Mexico was made by Dr. David L. Langebartel and John R. Winkelmann of the Department of Zoology, University of Illinois. They collected fecal specimens from 13 bats and 6 rodents, placed them in 2.5% potassium bichromate solution, and brought them to Urbana for examination.

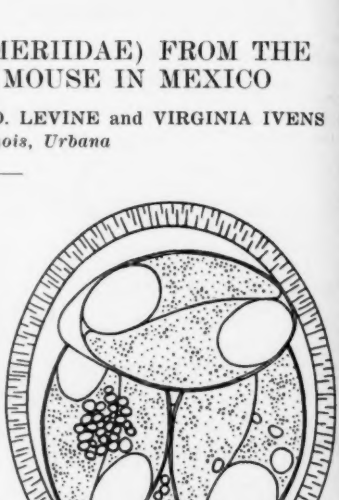
Each sample was mixed thoroughly, placed in a thin layer in a Petri dish at room temperature for a week to sporulate, and stored in a refrigerator. The samples were examined after sugar flotation, using a Leitz Ortholux microscope with apochromatic objectives.

No coccidia were found in the bats, but one new species and one previously described species of *Eimeria* were found in the rodents.

The skins and skulls of the host animals are preserved in the University of Illinois Natural History Museum. The numbers given with the host designations are those of the host animals in the museum.

Acknowledgments

We should like to express our appreciation to Dr. Langebartel and Mr. Winkelmann for providing the specimens and to Dr. Donald F. Hoffmeister, Director of the Museum, for making final identifications of the hosts.



Results

Eimeria couesii n. sp.

Diagnosis: *Eimeria*: Oocysts (Fig. 1) ellipsoidal, pale yellowish. Five sporulated oocysts were 20-23 by 17-20 microns with mean of 21.4 by 18.0 microns; length-width ratio was 1.20; wall somewhat rough and pitted, heavy, composed of single layer about 1.3 microns thick, with radial striations. Micropyle absent. Oocyst residuum absent. Oocyst polar granule present. Sporocysts ovoid; seven measured 10-14 by 7-8 microns with mean of 11.7 by 7.7 microns; length-

width ratios ranged from 1.2 to 1.8, mean of 1.53. Stieda body present. Sporozoites oriented longitudinally in sporocysts, with large clear yellowish globule at large end. Sporocyst residuum composed of rather loose granules or absent.

Host: Rice rat, *Oryzomys couesi couesi* (No. 18,833)

Location: Feces.

Locality: Oaxaca, Mexico.

The oocysts of *E. couesii* have been compared with the descriptions of all the other species of *Eimeria* reported from rodents. They differ from them all. However, since it has not been possible in any cross transmission experiments to infect rodents of one genus with *Eimeria* species from rodents of another genus, it is not considered necessary here to differentiate *E. couesii* formally from species of *Eimeria* other than those which have been reported from rodents of the genus *Oryzomys*. The only one of these is *E. oryzomysi* Carini, 1937 from *Oryzomys* sp. *E. couesii* differs from *E. oryzomysi* in having a polar granule, in lacking an oocyst residuum, and in heavy, striated rough oocyst wall rather than a smooth, thin one.

Eimeria baiomysis Levine, Ivens and Kruidenier, 1958

This species was found in a pygmy mouse, *Baiomys musculus* (No. 18,832), collected at Oaxaca, Mexico. Only three sporulated oocysts were seen. They measured 23-24 by 20-21 microns.

E. baiomysis was originally described from *Baiomys taylori* from Queretero, Queretero, Mexico. The present report is a new host species record.

Summary

Eimeria couesii n. sp. is described from the rice rat, *Oryzomys c. couesi* from Oaxaca, Mexico. Its oocysts measure 20 to 23 by 17 to 20 microns. *E. baiomysis* Levine, Ivens and Kruidenier, 1958 is reported from the pygmy mouse, *Baiomys musculus*, from the same locality, a new host record.

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TWO APPLICATIONS OF ELEMENTARY NUMBER THEORY

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INTRODUCTION

This note is concerned with two applications of elementary number theory to numerical quantification theory. The first application deals with a numerical aspect of symbolic logic and the second application is directed toward determining a "shortcut" procedure for indicating when a certain class of integers divides another class of integers. The results are given in terms of some general theorems and some specific examples.

SYMBOLIC LOGIC

For compactness of notation, frequently one represents a sequence of binary digits as a decimal integer with fewer digits (Caldwell, 1958, and Mullin, 1958). However, such a procedure is accompanied by the apparent difficulty of quickly regenerating from the decimal integer either some or all of the binary digits. Hence one is motivated to consider operations involving only the decimal integers to retrieve some or all of the binary digits (Mullin, 1958, and Abrahams, 1955). A method to effect this wish is given in the corollary of the following:

Theorem 1.1: Put $d = \sum_{i=0}^{n} a_i B^i$, where B is some integer greater than *1*, each a_i $(i=0,1,...,n)$ is an integer satisfying the condition $0 \leq a_i < B$ and n is a non-negative integer. Put $P_k = [\frac{d}{B^k}]$, where if a is real, $[a]$ is the greatest integer not exceeding a. Then $P_k \equiv a_k \pmod{B}$, $(k = 0, 1, ..., n)$.

Proof: $\frac{d}{B^k} = \sum_{i=1}^{n-k} a_{i+k} B^i + a_k + \sum_{i=1}^{k} a_{k-i} B^{-i}$.

Put $f_k = \sum_{i=1}^{k} a_{k-i} B^{-i}$. Since $max\ a_j = B-1$, then

$0 \leq f_k < (B-1) \sum_{i=1}^{\infty} B^{-i} = 1$.

Putting $S_k = \sum_{i=1}^{n-k} a_{i+k} B^i$, notice that there exists an integer I_k such that $S_k = B \cdot I_k$.

Hence $P_k = S_k + a_k + f_k = B \cdot I_k + a_k$.

Therefore, $P_k \equiv a_k \pmod{B}$.

Definition 1.1: The decimal integer d is said to contain 2^k in its binary number representation if and only if $a_k = 1$ $(k = 0, 1, ..., n)$ in $d = \sum_{i=0}^{n} a_i 2^i$.

Corollary 1.1: The decimal integer d contains 2^k in its binary number representation if and only if $[d \cdot 2^{-k}]$ is odd.
Proof: Put $B = 2$ in Theorem 1.1.
Example 1.1: Does 94 contain 2^2 in its binary number representation?
Consider,

$$[\frac{94}{4}] = [23\ 1/2] = 23, \text{ odd.}$$

Therefore, 94 does contain 2^2 in its binary number representation. In fact 94 is a brief representation for *1 0 1 1 1 1 0*, where the *1* in the third position from the right indicates the presence of $1 \cdot 2^2$.

C^n | A; A, C, n INTEGERS

A certain class of problems have the *a priori* condition that only those

integers which satisfy any other conditions of the problem are to be called solutions. This is the case with Diophantine analysis (Landau, 1958). The following results are useful, in some instances, for the purpose of giving a quick check to determine whether the *a priori* necessary condition is satisfied.

Theorem 2.1: Put $d = \sum_{i=0}^{m} a_i B^i$, where B is some integer greater than 1, each a_i $(i = 0, 1, ..., m)$ is an integer satisfying the condition $0 \leq a_i < B$ and m is a non-negative integer. Put $d^* = \sum_{i=0}^{n-1} a_i B^i$, where n is an integer satisfying the condition, $0 \leq n \leq m$. Put $\bar{d} = \sum_{i=n}^{m} a_i B^i$. If, and only if,

(i) there exists an r_1 such that $0 \leq r_1 < C^n$ and $d^* \equiv r_1 \pmod{C^n}$

and (ii) there exists an r_2 such that $0 \leq r_2 < C^n$ and $\bar{d} \equiv r_2 \pmod{C^n}$, implies either

(iii) $r_1 + r_2 = 0$ *or* $r_1 + r_2 = C^n$

then $C^n \mid d$.

Proof:

(1) $d^* = I_1 C^n + r_1$, where $0 \leq r_1 < C^n$ and I_1 is some integer,

(2) $\bar{d} = I_2 C^n + r_2$, where $0 \leq r_2 < C^n$ and I_2 is some integer.

But,

(3) $d = d^* + \bar{d} = (I_1 + I_2) C^n + (r_1 + r_2)$.

The "if" case is valid since, by hypothesis, either $(r_1 + r_2) = \begin{cases} 0 \\ C^n, \end{cases}$ but in either case $C^n \mid d$.

To show the "only if" case assume the hypothesis and the negative of the conclusion and arrive at the following contradiction:

By hypothesis, there exists an integer I_3 such that

(4) $d = I_3 C^n$.

Therefore, from (3) and (4) $C^n \mid (r_1 + r_2)$. But from (1) and (2), $0 \leq (r_1 + r_2) < 2C^n$, that is, $0 \leq \frac{(r_1 + r_2)}{C^n} < 2$.

The negative of the conclusion asserts that $\frac{r_1 + r_2}{C^n} \neq 0$ and $\frac{r_1 + r_2}{C^n} \neq 1$. Thus we arrive at the assertion that $C^n \nmid (r_1 + r_2)$.

Corollary 2.1: If $C^n \mid \bar{d}$ and $C^n \mid d^*$, then $C^n \mid d$.

Proof: $r_1 = r_2 = 0$ and apply theorem 2.1.

Corollary 2.2: If

(i) $C \mid B$ or $C \mid a_i$, $(i = n, n + 1, ..., m)$

and

(ii) $C^n \mid d^*$, then $C^n \mid d$.

Proof: If $C \mid B$ *or* $C \mid a_i$, $(i = n, n + 1, ..., m)$ then $C^n \mid \bar{d}$. Now apply corollary 2.1.

Example 2.1:

Does $2^4 \mid 3\ 1\ 4\ 1\ 5\ 9\ 2\ 6\ 5\ 3\ 6$?
Yes! Since $8 \mid 5\ 3\ 6$.

Does $2^4 \mid 2\ 7\ 1\ 8\ 2\ 8\ 1\ 8\ 2\ 8\ 5$?
No! Since $1\ 6 \nmid 8\ 2\ 8\ 5$.

Summary

Five general propositions dealing with the application of elementary number theory to numerical aspects of symbolic logic and Diophantine analysis are proved. For concreteness, some specific examples are given to demonstrate the use of the propositions.

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COMPARISON OF HABITATS OF TWO CRAYFISHES OF THE GENUS *PROCAMBARUS* IN ILLINOIS AND LOUISIANA

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As part of a study of the biology of the crayfishes of central and southeastern Illinois, the author investigated the aquatic habitats of the crayfishes found in that state (Brown, 1955). The limnological data consisted of records of the temperature of the water, dissolved carbon dioxide, hydrogen-ion concentration, dissolved oxygen, and total alkalinity. Additionally, data were compiled on physical factors such as the general type of habitat, types of bottoms, and the turbidity of the water.

Subsequently, during a study of crayfishes in Louisiana, two forms, *Procambarus clarkii* (Girard) 1852 and *P. blandingii acutus* (Girard) 1852, which also occur in both of these rather widely separated states, were collected. According to Hagen (1870), *P. b. acutus* has been reported in both Illinois and Louisiana over a long period of time, while *P. clarkii* appears to be a relatively recent migrant into Illinois (Brown, 1955). In the light of these facts the author became interested in comparing the habitats of these forms in the two states. It was hoped that such an investigation might clarify the factors responsible for the difference in the distributional pattern and indicate the probability of the success of *P. clarkii* in Illinois.

Materials and Methods

The comparisons of *P. clarkii* are based on only nine collections in Alexander, Massac, and Pulaski counties in Illinois, and records from ten collecting stations in East and West Baton Rouge parishes, Louisiana. On the other hand, *P. b. acutus* was collected throughout Illinois, while the data from Louisiana were obtained from nine stations in East and West Baton Rouge parishes. It is unlikely that these data represent the true range of variation over the entire state of Louisiana. However, it is felt that they are sufficient to serve as a basis of comparison of the types of habitats occupied by these two forms in the two rather widely separated areas.

Standard limnological methods were used (Welch, 1948). Temperature determinations were made with a Centigrade chemical thermometer. La Motte colored glass standards were used for the hydrogen-ion tests. Total alkalinity values were arrived at by titrating .02N sulfuric acid against methyl orange, and the Rideal-Stewart modification of the Winkler Method was used in the determinations of dissolved oxygen. A Kemmerer water sampler was used for collecting the samples for both of these determinations. A nomogram based on Moore's equation (1939) was used to find values for dissolved carbon dioxide. The references to turbidity are estimates of relative clearness of the water rather than to exacting quantitative measurements.

Results and Discussion

Since the temperature of the water varies with the climate, the occurrence of the two forms in the two states, whose mean annual temperatures are quite different, suggests that both forms have a very wide range of tolerance to varying temperatures (Table 1). The data agree with those of Park (1945); he found that pond or lentic crayfishes are found predominantly in lentic situations (Table 2). A comparison of the mean temperatures of the waters in which they were found suggests that temperature might be an important factor in that the mean temperature of the water of the habitat differs by only 1.5°C. for *P. b. acutus* and 1°C. for *P. clarkii* in the two states. However, the ranges are based on samplings during the warmer season.

According to Welch (1951), the literature contains numerous positive contentions that pH is an important limiting factor for certain organisms. However, he also points out that other workers regard pH as of secondary importance, and that some investigators have claimed for some organisms no correlations of any sort with the pH range as it occurs in natural, unmodified waters. The latter appears to be true for these crayfishes (Table 1). The mean of the hydrogen-ion concentrations for waters inhabited by *P. b.*

Table 1.—Chemical Data from the Habitats of the Crayfishes.

	Temperature °C		Hydrogen-ion		Dissolved O_2[1]	
	Range	Mean	Range	Mean	Range	Mean
P. clarkii						
Illinois	22–34	27	6.8–8.0	7.3	1–11.3	4.1
Louisiana	20–33	28	6.8–7.6	7.0	1.3–7.4	4.0
P. b. acutus						
Illinois	8–35	23	6.3–8.2	7.2	1–12	5.0
Louisiana	20–33	24.5	6.8–7.6	7.1	1.8–7.4	4.5

	Dissolved CO_2[1]		Total alkalinity[1]	
	Range	Mean	Range	Mean
P. clarkii				
Illinois	1–50	13	59–202	112
Louisiana	0.14	3.8	13–217	59.5
P. b. acutus				
Illinois	0–50	10	50–463	190
Louisiana	0–13	4.2	13–217	88.3

[1] In parts per million.
Illinois data—spring, summer, fall, 1953, 1954.
Louisiana data—spring, summer, 1957, 1958.

acutus in the two states differs by only 0.1 and that of *P. clarkii* by only 0.3. This suggests a preference. Both forms do, however, inhabit waters in the two states whose hydrogen-ion concentrations are about the same, at least during the periods tested.

Both of the crayfishes live in waters whose dissolved oxygen concentration becomes either rather low or very high (Table 1). The dissolved oxygen concentrations range higher in Illinois for both forms because they also occur in streams which have rapids and other means of aeration. The means for both forms in the two states do not appear to be significantly different, varying in the case of *P. b. acutus* by 0.5 p.p.m. and that of *P. clarkii* by only 0.1 p.p.m. These data suggest that both crayfishes live in waters with essentially the same oxygen concentration in the two states.

There seems to be a greater difference in the concentration of the dissolved carbon dioxide than in any of the previous factors. These results may best be explained on the basis of the data from the individual samplings. This is particularly true in the instance of the samplings in Louisiana. In six instances the carbon dioxide concentration was either 1 or 0 p.p.m., and, therefore, the means are low. A comparison of the means of the dissolved carbon dioxide concentrations suggests that this factor may be critical. However, it is also noted that both the means and the ranges are uniformly high for both crayfishes in Illinois and low for both in Louisiana.

The waters in the southern part of Illinois showed lower total alkalinity values than did those of the other parts of the state. *P. clarkii* was found only in the southern part of Illinois. The total alkalinity values for the habitats in Louisiana ran even lower than those of southern Illinois (Table 1). Maximal alkalinity of the waters in Illinois inhabited by *P. b. acutus* ranged up to 463 p.p.m., that of the habitat of *P. clarkii* was 202 p.p.m.; in Louisiana these values were 217 p.p.m. in each case. Therefore, it is seen that the total alkalinity ranges for both *P. clarkii* and *P. b. acutus* in Illinois and Louisiana are rather wide. The total alkalinity values suggest that there is a considerable difference between the habitat preferences of these forms in the two states, but both forms tolerate wide ranges of alkalinity.

Rhodes (1944) wrote that *P. b. acutus* is "rather tolerant regarding ecological factors", and Hobbs and Marchand (1943) usually found *P. clarkii* in lentic situations in Kentucky and Tennessee. During this study both forms were usually found in situations comparable to those reported from other areas. The general types of habitats from which the two forms were collected in both states do not differ greatly. The higher percentage of *P. clarkii* in running water in Louisiana (Table 2) is probably due to abnormally frequent rains while the collections were being made; this resulted in the occurrence of crayfishes in running water in streams which are normally intermittent.

Rhoades (1944) found *P. clarkii* predominantly in mud-bottomed sloughs or temporary situations. The information gained in investi-

gating the two forms in Illinois suggests that both crayfishes seem to exhibit a preference for mud-bottomed situations. The percentages of collecting stations with mud bottoms from which both forms were collected in both states are almost identical (Table 2). The fact that *P. b. acutus* was on sandy and rocky bottoms in Illinois may be attributed to the fact that such habitats are relatively abundant in that state.

The final aspect for consideration is that of turbidity. It was noted while collecting various species of crayfishes that these two forms, in particular, seemed to show a decided preference for turbid waters. During the present study only *P. b. acutus* was found in clear water. With the exception of the instances in which *P. b. acutus* was collected from clear water situations, the turbidity of the waters from which the two forms were collected in the two states is strikingly similar (Table 2).

TABLE 2.—Distribution of Crayfish Related to Physical Factors in the Habitat.[1]

WATER	Running	Intermittent	Pond	Temporary pond
P. clarkii				
Illinois	..	44	12	44
Louisiana	40	20	10	30
P. b. acutus				
Illinois	37	50	7	6
Louisiana	50	12.5	12.5	25

TYPES OF BOTTOMS	Soft mud	Sandy	Rocky	Sand and mud	Clay
P. clarkii					
Illinois	100	..	..	....	....
Louisiana	90	..	..	....	10
P. b. acutus					
Illinois	71	9	5	9	6
Louisiana	75	..	..	12.5	12.5

TURBIDITY	Low	Medium	High
P. P. clarkii			
Illinois	....	34	66
Louisiana	....	60	40
P. b. acutus			
Illinois	15	45	40
Louisiana	12.5	50	37.5

[1] Expressed in percentages of occurrence of crayfish.

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The author is indebted to Southern University for the use of equipment and facilities for the data from Louisiana. Gratitude is also expressed to Dr. Max R. Matteson of the University of Illinois who supervised the doctoral problem from which the Illinois data were taken and gave valuable advice and suggestions for the other work reported herein.

Summary

The limited section of southern Illinois from which *P. clarkii* was collected affords essentially the same types of physical conditions as those found in Louisiana where this species abounds. This is not true for *P. b. acutus*. The present study, like that of Hobbs and Shoup (1942), showed no evident correlation between alkalinity, pH, dissolved oxygen, dissolved carbon dioxide, or temperature and the distribution of the crayfishes. The data seemed to indicate a marked similiarity of conditions, both physical and chemical, under which the two crayfishes live in the two states. However, the conditions under which *P. clarkii* lives in both Illinois and Louisiana seem to be more nearly the same than do those under which *P. b. acutus* lives in the two states; these conditions might serve as a limiting factor for the further dispersal of *P. clarkii* in Illinois and adjacent areas.

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ECOLOGICAL INTERPRETATION OF DATA ON ARCHAEOLOGICAL SITES: THE MODOC ROCK SHELTER

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Introduction

At the eastern edge of the Mississippi flood plain about two miles southeast of Prairie du Rocher, Randolph County, Illinois, is the Modoc Rock Shelter. It is one of the oldest and longest occupied Indian sites now known in North America. Radiocarbon determinations have indicated that it was occupied as early as 8000 B.C. and inhabited until after 2000 B.C., a time span of over 6000 years (Fowler, Winters and Parmalee, 1956; Deuel, 1957; and Fowler, 1959). During most of its history, the Modoc Rock Shelter was occupied by peoples of the Archaic Stage of cultural development (Willey and Phillips, 1959). Later occupations of the Modoc Rock Shelter were sporadic, and some evidence indicates the site was occasionally utilized by Indians as late as 1200 A.D.

The basic contours of an overhanging bluff were probably formed by the torrential waters from the Valders substage of the Wisconsin glaciation (M.M. Leighton, pers. comm.). This substage reached its maximum around 9000 B. C. (Rubin, 1955: 453). The Modoc Rock Shelter was probably first occupied soon after the flood waters receded, for the first evidence of such occupation was found on bed rock. During the course of human occupation the site built up, through natural and human agencies, to a depth of more than 27 feet above this rock.

The Illinois State Museum conducted archaeological excavations at the Modoc Rock Shelter during the summers of 1952, 1953 (with cooperation of Department of Anthropology, University Chicago), 1955 and 1956. Thousands of artifacts of human manufacture, chert chips, mollusks, animal bones, human burials, and other indications of human habitation were recovered.

Ecological Interpretation of Animal Remains

The large quantity of bone and shell recovered at the Modoc Rock Shelter Site has proved to be of especial significance to both the zoologist and the archaeologist. For the zoologist, the variety of species represented and the number of remains provide an index to the prehistoric distribution and possible abundance of the animals inhabiting or migrating through this area. To the archaeologist, these faunal materials supply food habits data of these Archaic people. The presence of exotic species in the midden deposits suggest trade routes and/or barter, while the occurrence of species typical of a particular habitat indicates the locality hunted by the Indian.

More than 92,000 pieces of bone were removed from these midden deposits; nearly 8,000 bone remains were identifiable to genus or species. Approximately 17,000 shells of fresh-water mussels and terrestrial

and aquatic gastropods were identified. With but few exceptions, all of the species of mussels and animals identified from the midden debris still occur in that general region of southwestern Illinois.

Mollusks

Fresh-water mussels were common at this site and apparently formed an important source of food for the Indian; they would have been easily obtainable and available throughout most of the year. Approximately 2,900 shells of mussels, representing 36 species, were identified, and the majority of these were typical large-river forms and had probably been collected in the Mississippi River. However, the presence of certain species characteristic of shallow, mud-bottomed ponds and sloughs (*e.g. Uniomerus tetralasmus*) suggests that the Indians hunted the shallow backwaters and sloughs as well as the main river for mussels (Parmalee, 1956).

None of the numerous sites previously excavated in Illinois produced the quantity and variety of species of snails recovered at the Modoc Rock Shelter. Although the vast expanse of time involved during the periods of human occupancy would allow for the probable accumulation of such quantities of terrestrial gastropods, the abundance of certain aquatic species (more than 4,400 specimens of *Campeloma* spp.) also points to the use of snails as a source of food. Matteson (1953) concluded that terrestrial gastropods in the midden heap of a Hopewellian site in Pike County, Illinois, ". . . were not an item of diet of the Indians . . . . They became a part of the kitchen midden while seeking food." Probably some of the specimens recovered at the Modoc Rock Shelter occurred there naturally, but the high concentration of aquatic as well as terrestrial forms indicates that snails were eaten.

Of the more than 14,000 identified gastropod shells recovered at the Modoc Rock Shelter less than two dozen bore evidence of having been worked or altered in any way. Four shells of Campeloma and 17 small specimens of *Anculosa praerosa* had been drilled or otherwise modified for use as beads. The latter species is of interest since it apparently occurs only in the lower Wabash and Ohio rivers in Illinois. These 17 specimens were possibly acquired through barter or during wanderings to the southeast. This paucity of worked shell artifacts compared with the huge quantity of mollusk remains suggests that their primary use was for food; in most instances it appears that the various species were collected in direct proportion to their abundance and availability.

Vertebrates

Judging from the variety of fishes, turtles, birds and mammals represented in the midden deposits, the Indian utilized extensively the local vertebrate fauna. In the instance of the whitetail deer, as well as many other species, it is obvious that the animal was intentionally killed for food and/or other purposes. However, the remains of small mammals such as chipmunks and mice which could have inhabited the site area raise the question as to whether or not these forms were eaten by the Indians.

Fishes.—A minimum of ten species of fishes was represented in the

midden debris; bones of the freshwater drum, catfish (*Ictalurus* spp.), gar, bowfin, and catastomids (buffalofish and suckers) were the most numerous. Most of the remains were of small specimens and more than 50% of all those identified were of "rough" fish—gar, suckers and bowfin; the smaller bullheads accounted for approximately 25% of the total. These fishes are known to inhabit commonly the shallower, quiet backwaters and sloughs; therefore, it appears that the Indians obtained most of their fishes from such habitats.

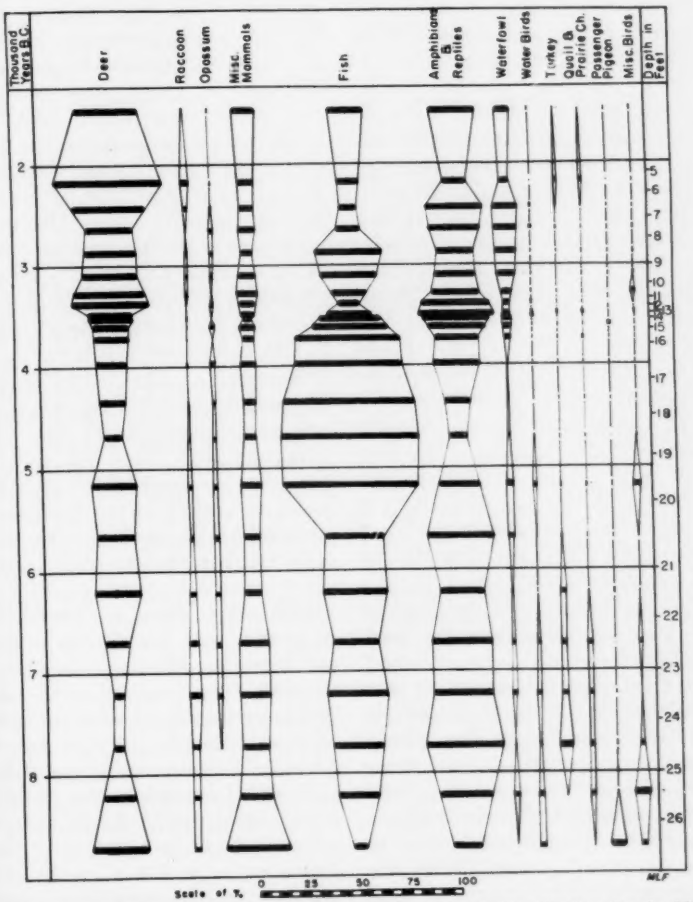

FIG. 1—Distribution of vertebrate remains by depth, Modoc Rock Shelter, Randolph County, Illinois. Length of bar represents proportion of category to total number of vertebrate remains from that depth.

Reptiles.—More than 800 snake vertebrae were found scattered throughout the occupation levels; no specimens were found associated with any of the human burials, and it is a matter of speculation as to whether snakes were eaten by these Archaic people or whether they died naturally at the site.

Turtles were apparently collected in large numbers as indicated by the nearly 2,000 shell fragments and sections. Remains of the locally abundant pond terrapin, *Pseudemys scripta*, and painted turtle, *Chrysemys picta*, were the must numerous. Correlated with the predominence of bullhead and "rough" fish bones, remains of turtles (species especially common in backwater areas) strengthen the hypothesis that the Indians hunted and collected this type of game in the overflow ponds and sloughs. Only eight bones of the soft-shelled turtle were recovered; *Trionyx* more typically inhabits the faster waters of the main river. Box turtles were taken in considerable numbers and, as evidenced by the numerous sections of scrapped and worked shell, the carapace was often used as a dish or utensil.

Birds.—At least 58 species of birds were identified from the more than 900 avian remains found, and it is apparent that this group of vertebrates provided an important source of food. The Modoc Site is situated along the Mississippi River which is one of the major waterfowl flyways; approximately 65% of the identified bird bones were those of ducks, geese and swans. With the occurrence of other aquatic and semiaquatic species such as the pied-billed grebe, American coot, sandhill crane, rails, bitterns, and shorebirds, it is apparent that the Mississippi River and especially the associated backwaters were hunted extensively for avian game.

Although the data indicate that much of the game was taken in river and marsh habitats, remains of species associated with dry upland areas, such as the greater prairie chicken, bobwhite, eastern cottontail and spotted skunk (Parmalee and Hoffmeister, 1957), suggest limited hunting in the prairie and semi-brush areas away from the river. Bones of the extinct passenger pigeon (Parmalee, 1958) were of special interest; these birds were probably captured on the wooded bluffs during migration. In comparison with the total number of identified bird bones, the precentage (7) of turkey bones was small.

Mammals.—The whitetail deer was singly the most important vertebrate species taken by the Indian (approximately 70% of the total identified mammal bones) and it apparently served as the meat staple. Several smaller species such as the muskrat, raccoon, squirrel (*Sciurus* spp.), opossum, and eastern cottontail were taken in considerable quantities and constituted some of the more important supplements of the diet. The first two species were definitely associated with an aquatic habitat, although the squirrels and opossum could have been taken in the wooded uplands or the floodplain forests along the river. A rather extensive use of the opossum by these Archaic people is noteworthy, since remains of this primitive mammal are rare in sites of more recent periods in Illinois.

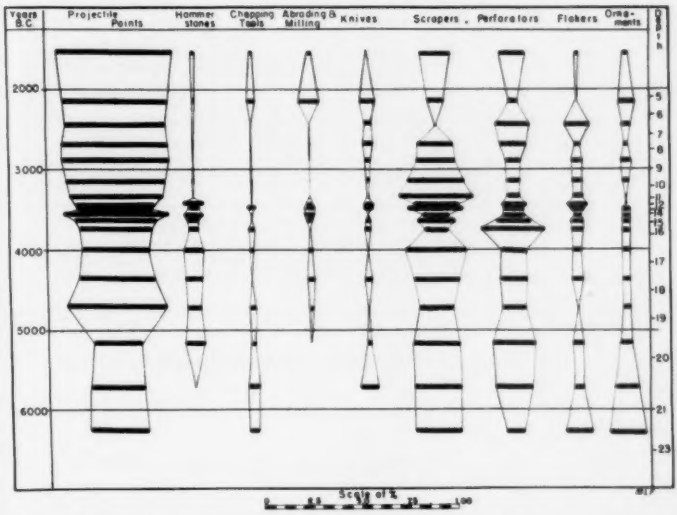

FIG. 2.—Distribution of artifacts by use categories and depth found, Modoc Rock Shelter, Randolph County, Illinois. Length of bar represents proportion of category to total number of artifacts found at that depth.

The presence of such species as chipmunk, mice (*Peromyscus, Microtus*), plains pocket gopher and other small animals often considered as undesirable for food and which could have lived naturally in the area of the site raises the question as to whether or not these forms were eaten by the Indians.

Bone Artifacts

Animals were taken primarily for food although in many instances bones of one or more species served in a secondary capacity as ornaments, tools or utensils. Several artifacts manufactured from deer antlers (tines, flakers) and limb bones (*e.g.* awls fashioned from the ulna) were not uncommon while bone splinter awls occurred throughout most occupation levels. The tarsometatarsus of the turkey was also used to make awls. One of the most unique finds was a cache of approximately 160 goose (*Branta canadensis* and *Chen* spp.) radii and six tarsometatarsals of the sandhill crane associated with a human burial. Some of the radii had been made into awls but the majority were not altered. This find probably was a cache of raw materials for making awls, placed as a grave offering.

Ecological Conditions

The data indicate that ecological conditions were much the same throughout the history of the site. The well-represented species of animals were present in most levels of the site. One notable exception to this was the presence of the terrestrial gastropod, *Allogona profunda*, only in the lowest strata; presently this species occurs only in the north-

TABLE 1.—Vertebrate Remains from Modoc Rock Shelter: Mammals, Fishes, Amphibians and Reptiles.

Depth, feet	Mammals					Fishes	Amphibians, reptiles
	Deer, Elk	Raccoon	Opossum	Others	Unident.		
Above 5	115	7	1	47	3102	65	86
5-6	72	6	1	10	1381	15	16
6-7	100	6	1	17	1918	22	80
7-8	207	11	14	67	5885	193	236
8-9	503	45	66	138	2872	770	425
9-10	399	35	19	122	9328	388	292
10-11	342	18	10	95	7246	166	220
11-12	140	6	2	27	3342	41	125
12-13	95	3	5	31	2968	100	164
13-14	249	14	9	53	7051	338	370
14-15	139	5	3	57	4862	301	220
15-16	115	4	14	37	3854	332	144
16-17	96	7	1	43	4555	317	138
17-18	99	9	.....	50	4087	485	106
18-19	68	10	10	37	3345	494	63
19-20	57	8	5	27	2603	179	54
20-21	67	6	6	28	2517	104	117
21-22	60	10	5	23	1915	99	59
22-23	34	12	9	25	1548	58	77
23-24	7	7	3	17	664	37	35
24-25	8	7	2	21	1101	36	60
25-26	12	3	.....	13	336	16	20
26-27	6	1	.....	7	134	2	1
27-28	2	.....	.....	2	24	.....	3

TABLE 2.—Vertebrate Remains from Modoc Rock Shelter: Birds and Totals.

Depth, feet	Birds							Totals	
	Waterfowl	Water birds	Turkey	Quail, prairie chicken	Passenger pigeon	Misc.	Unident.	All	Ident.
Above 5	23	1	2	0	1	5	60	3,515	353
5-6	6	0	2	2	0	1	23	1,535	131
6-7	36	3	2	3	2	1	115	2,306	273
7-8	114	13	8	9	2	14	396	7,169	888
8-9	268	16	12	17	3	35	863	6,033	2,298
9-10	135	8	3	8	1	27	513	11,278	1,437
10-11	47	5	2	7	0	22	180	8,355	929
11-12	11	3	2	1	0	2	69	3,771	360
12-13	16	5	5	4	2	6	96	3,500	436
13-14	53	18	3	3	2	11	321	8,495	1,123
14-15	35	2	4	3	16	9	268	5,924	794
15-16	25	3	2	6	1	2	120	4,659	685
16-17	5	1	4	4	4	6	69	5,250	626
17-18	8	4	2	2	1	1	63	4,917	767
18-19	10	1	4	1	0	2	47	4,092	700
19-20	11	4	2	2	1	9	38	3,000	259
20-21	13	3	3	1	1	3	43	2,912	352
21-22	4	2	7	2	2	1	46	2,235	274
22-23	4	4	6	5	0	5	56	1,853	249
23-24	3	3	4	3	1	0	12	796	120
24-25	1	2	8	3	1	3	30	1,283	152
25-26	2	2	0	2	1	6	10	423	77
26-27		1	0		1	1	12	166	20
27-28					1			32	8
								92,504	13,311

ern half of Illinois and is associated with a cool, damp, wooded habitat. This may correlate with the geological data which indicate that the site was first occupied soon after the Valders Substage of the Wisconsin glaciation reached its maximum.

Although remains of a few species suggest the utilization of upland prairie and semi-bushy regions by the Indian, the majority of the animals were apparently taken in the forested flood plain and backwater habitats of the Mississippi River. At the present time, therefore, interpretation of the faunal data leads to the conclusion that the local habitat remained relatively unchanged with the exception of earlier periods which were apparently somewhat cooler and damper.

Correlation of Artifacts With Animal Types

To study any possible changes in the use of fauna through time, the vertebrate remains were divided into broad categories as well as species. The proportion of each of these categories (Tables 1 and 2) to the total number of vertebrate remains was calculated for each one-foot level of the site. These proportions were plotted on a graph (Fig. 1) with the levels spaced on a time axis as indicated by the radiocarbon assessments.

In the periods of the earliest occupation of the site (8000-6000 B.C.), the inhabitants made use of practically all animals available to them for food. For example, the category of miscellaneous mammals was more strongly represented in that period than in any later periods. Birds, with the exception of waterfowl, were more common in the midden debris of the lower levels than in the upper strata.

In the middle periods of the site's occupancy (6000-3000 B.C.) fishes dominated the remains, thus indicating that they were used more extensively for food than previously. A separate analysis of the mollusks by one-foot levels indicated that this was also the period when aquatic snails and clams were most extensively utilized at the Modoc Rock Shelter.

In the later period of the Archaic habitation (3000-2000 B.C.), all categories decreased except deer and waterfowl; remains of these animals became much more plentiful. This suggests that the Modoc hunters had become more selective in hunting and that, perhaps, the Modoc Rock Shelter became a hunting camp occupied only in the fall of the year when deer and waterfowl would have been most abundant.

A similar analysis was undertaken of the artifacts found at the different levels. These artifacts were broken down into use categories to indicate the different activities of the people. The analysis of these categories (Table 3) was carried out in the same way as described above for the vertebrate remains. The proportions of each of these tool categories for the various levels are shown in Figure 2. There are no data from before 6500 B.C. since, for this type of analysis, too few artifacts were found in the lower levels.

Projectile points, suggesting hunting activities, increased through time, and between 3000-2000 B. C. they accounted for more than 50%

TABLE 3.—Analysis of Modoc Assemblage by Use Categories.

Depth, feet	Projectile pts.	Hammer stones	Chopping tools	Milling, abraders	Knives	Scrapers	Perforators	Flakes	Ornaments	Totals
Above 5	40		1	1		11	9	2	3	67
5-6	14	1	1	3	2	2	1		2	26
6-7	20				2	4	7	5	1	39
7-8	80	1	1	1	6	28	21	5	3	146
8-9	135	3	1	1	8	50	19	16	13	246
9-10	124	7	4	1	6	69	16	131	8	240
10-11	118	3	2		2	103	19	11	2	261
11-12	31	9	1		3	17	9	8	1	78
12-13	39	5	3	2	4	30	10	6	4	103
13-14	64	12	1	6	1	16	12	3	3	119
14-15	35	4	1	4	2	16	15	4	3	84
15-16	30	4	2	2	2	5	26	5	2	78
16-17	38	13	4			34	14	4	4	114
17-18	38	8		2	4	22	14	5	4	97
18-19	37	5	2	2	1	13	9	1	3	73
19-20	12	5	1	1	1	12	11	3	3	49
20-21	12		2		4	10	8	2	5	43
21-22	6		1			5	2	3	4	21

of the tools. Domestic tools, indicating various manufacturing and living activities such as hammerstones, chopping tools, perforators and scrapers, were most common in the period between 6000 and 3000 B.C. but negligible from 3000 to 2000 B.C. Knives or cutting tools, although well represented between 6000 and 5000 B.C., had their strongest consistent representation between 3000 and 2000 B.C., the same as projectile points. Ornaments were most common around 6000 B.C. and decreased proportionally thereafter.

The analysis of the artifacts indicates that the Modoc Rock Shelter was a general habitation site between 6000 and 3000 B.C. and that many different hunting and domestic activities were carried on there. After 3000 B.C., projectile points and knives, *i.e.* hunting tools, became more important and other activities were negligibly represented. These data correlate with the analysis of the faunal data which points to the probability that in the earlier periods, the Modoc inhabitants hunted and gathered a great variety of wild food. In the middle period they utilized more extensively freshwater mussels, snails, and fish which were locally available. In the late period they tended to specialize in the hunting of deer and waterfowl.

In terms of the process of adaptation to the local environment, the human habitation of Modoc Rock Shelter can be divided into three sequent phases based upon the data on the fauna and artifacts presented above: *Phase I*) The Initial Occupation (8000-6000 B.C.). The site was first occupied by people who utilized all food resources available; *Phase II*) The Period of Localized Adaptation (6000-3000 B.C.). In this phase the Modoc inhabitants learned to supplement more extensively their staple deer meat diet with other food sources available in the immediate area. These were fish, clams, and snails in the tributaries, backwaters and sloughs of the Mississippi River; *Phase III*) The Period of Specialized Adaptation (3000-2000 B.C.). In this phase the Modoc inhabitants became specialists in hunting deer and waterfowl and probably occupied the site primarily as a hunting camp. Previously it had been a general habitation area. They probably carried on other activities in different specialized camps and at different seasons of the year. Exemplary of such other specialized camps would be the Ferry Site in Hardin County, Illinois (Fowler, 1957), where the tools indicated that it was a nut collecting, manufacturing, and ceremonial site. Another type of site was the large shell middens in Kentucky (Webb, 1946) which indicates that the collection of mussels (probably in the summer when rivers were at low level) was the basis of subsistence.

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INTERRELATIONS BETWEEN EMPIRICAL FORMULAE FOR SPECTROSCOPIC CONSTANTS OF DIATOMIC MOLECULES

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Introduction

The spectra of diatomic molecules have been studied to obtain the values of certain constants which characterize the structure of a molecule and its energy levels. The variation of potential energy, U, as a function of the internuclear distance, r, may be represented graphically by the conventional potential energy curve.

Not all spectroscopic constants are known for all molecules or even for all states of a single molecule. Various empirical relations have been proposed to predict the values of unknown constants from those known experimentally. These relations have also been used to provide insight into bonding models of molecules. Examples of these relations are found in the early work of Badger (1934) and the recent work of Smith (1956). In general, specific relations have been used to make predictions for molecules which have some common characteristics.

In this paper some of the empirical relations are examined as to their range of validity. Some standard techniques of mathematical treatment of experimental data are applied to these relations to determine whether *a priori* a certain empirical relation will be more valid than another relation. These techniques are also used to suggest two new empirical relations which should be of use in prediction of unknown spectroscopic constants.

The following notations are used to represent the various spectroscopic constants: 1) r_e, internuclear distance at the equilibrium distance; 2) D_e, dissociation energy; 3) k_e, force constant; 4) α_e, constant related to the rotational constant, B_e; 5) $\omega_e x_e$ and 6) $\omega_e y_e$, both of which are constants related to the anharmonicity (*i.e.*, the deviation from a true parabola at the equilibrium minimum).

Relation to Analytical Expressions

Many investigators have sought to express the experimental potential energy curve as a mathematical equation. This has been done in both open and closed form. The closed expressions have been selected to reproduce the general shape of the curve, to obey certain limiting conditions (*cf.* Varshni, 1957), and to reproduce certain of the known spectroscopic constants. These known constants are either placed directly in the mathematical expression or used as boundary conditions to determine the values of the arbitrary constants used in the mathematical equation. In general, the more arbitrary or fixed constants which are used in the mathematical equation, the better is the "fit" to the experimental curve. In the literature, equations are found containing as few as two constants (Kratzer, 1922) and one with five constants (Hulburt and Hirschfelder, 1941).

Dunham (1932) proposed a mathematical equation in the form of a Taylor series. Although this expression has poor convergence properties, it does have the advantage of allowing flexibility in the choice of the number of constants used to "fit" the experimental curve. Dunham has also shown that the coefficients of the power series are related to the known spectroscopic constants. For example, the coefficient of the square term (the second derivative of the equation divided by two factorial) is equal to k_e.

The application of Dunham's formulae to the closed form expressions leads to analytical expressions between the known spectroscopic constants. These analytical expressions are identical in functional form to the empirical relations between spectroscopic constants proposed by various authors. However, it is not necessarily true that an equation which is a good "fit" to the experimental curve will produce a functional relation between known constants which is also good. In fact, these functional relations being derived from differentiation depend on the positioning of the constants in the analytical expression for the experimental curve. They also depend on whether arbitrary constants are used and adjusted to the boundary conditions or whether the known constants are placed in the analytical expression directly.

The analytical expression of Mecke (1927), Sutherland (1938), Varshni (1957), and Kratzer (1922) all lead to the relation

$$\frac{k_e r_e^2}{D_e} = C_2 \qquad (1)$$

where C_2 is a constant. The original expressions,

$$U = D_e \left[\frac{r - r_e}{r} \right]^2 \quad \text{Kratzer}$$

$$U = Ar^m e^{-ar} \quad \text{Varshni}$$

$$U = Br^{-m} - br^{-p} \quad \text{Mecke-Sutherland}$$

where A, a, B, b, m, and p are arbitrary constants, are examples of a two-parameter function, a three-parameter function, and a four-parameter function, respectively. The value of C_2 should be the same for all molecules. In practice, the value of C_2 differs when individual molecules, or groups of molecules, are considered. The functional form of C_2 which relates the known constants is the same. Thus, the more flexible Mecke-Sutherland equation, which would be expected to give a more faithful representation of the experimental curve, provides the same relation between k_e, r_e, and D_e as the less flexible Kratzer equation.

Comparative Test of Various Empirical Relations

The spectroscopic constants vary from a fivefold range (for r_e) to a thousand fold range (for α_e) for all molecules. An empirical relation that could be used to predict a spectroscopic constant would be expected to make predictions within a smaller range than the naturally occurring variation. The best relation would satisfy all possible diatomic molecules, but several useful relations have been found which satisfy certain groups of molecules.

The general procedure adopted in this work is to "fit" a particular group by finding the best arbitrary

constant for that group when the relation is put into a functional form similar to equation (1). The best constant is also determined for all molecules. The average deviation from these constants is tabulated in Table 1. (A random sampling indicated that a Least Squares Deviation treatment did not change general ordering of the empirical relations with respect to deviation from a good "fit".) A sample of 21 diatomic molecules was selected. No attempt was made to select molecules which had normal behavior in their spectroscopic constants. In fact, molecules were used (N_2, CO, and NO) whose D_e is in doubt, as well as molecules which are known to have abnormal values of the spectroscopic constants (Li_2, Na_2, and K_2). The values of the spectroscopic constants used in these tests were taken from the values tabulated by Varshni (1957). The molecules were grouped according to similar chemical properties, as indicated by the Periodic Table. In each grouping of homopolar molecules, the atoms were selected from a given row or column of the Periodic Table. In each grouping of heteropolar molecules, one atom was selected from a given row or column and the other atom was the same throughout the grouping. The molecules comprising each group are listed in Table 1.

A comparison between the constancy of r_e ($r_e = C$) and $k_e r_e^2 = C_1$ is given in Table 1. The combination of two constants gives a much better "fit" within a given grouping of molecules but provides a worse "fit" when an attempt is made to

TABLE 1.—Comparison of Average Percentage Deviations.

Molecular groupings	C	C_1	C_2	C_3	$Ar_e^{-1}+B$	—L'	M'
Group VIIA-hydride (HF, HCl, HBr, HI)	16	1	21	13	1	9	11
Group IA-Group IA (Li_2, Na_2, K_2)	14	7	19	10	2	9	20
Group VA-Group VA (N_2, P_2)	27	16	17	36	..	5	13
Group IIB-hydride (ZnH, CdH, HgH)	4	4	24	21	17	17	28
Group VIIA-Group VIIA (Cl_2, Br_2, I_2, ICl)	8	2	14	8	7	8	10
Period 2-oxide (CO, NO, O_2)	3	12	17	14	10	6	7
Period 2-hydride (CH, OH, HF)	8	13	11	11	11	1	1
All molecules	34	59	46	38	2000	28	38

use a single constant for all molecules.

The deviations from a constant of an empirical relation combining three spectroscopic constants is also given in Table 1. This is the C_2 of equation (1). The values of the deviations from C_2 are much greater within a group than are those of C_1 but somewhat better for all molecules. This better behavior when all molecules are considered is fortuitous, as can be seen by examination of the column which gives the deviations for the two parameter relation, $k_eD_e^{-1} = C_3$. In general C_3 is better than the three-parameter relation, C_2, within selected groups and also is better when all molecules are considered.

The conclusion indicated is that the spectroscopic constants may be combined in empirical relations which are reasonably accurate in predicting the values of one constant, in a given grouping of molecules. This appears to result from a fortuitous compensation in variation of the spectroscopic constants themselves. A good relation is obtained only by a judicious grouping of the original constants and does not depend on the number of constants used in the relation. In general, the opposite behavior is observed in selecting a closed relation to represent the potential energy curve.

The usual techniques of "fitting" experimental data (Scarborough, 1955: 473) to an empirical relation employ two arbitrary parameters to give a better "fit" than one arbitrary parameter and three to give a better "fit" than two, and so forth. The analytical expression of Frost and Musulin (1954a) leads to an empirical relation of the functional forms $k_eD_e^{-1} = Ar_e^{-1} + B$. Previously a single constant, C_3, was used to describe the product $K_eD_e^{-1}$. This new functional form "fits" the product $k_eD_e^{-1}$ to a straight line function of r_e^{-1} by the use of two arbitrary constants, A and B. The constants A and B are determined in each grouping of molecules by the means of known experimental data. The deviations from a straight line are shown in Table 1. These deviations indicate that the adjustment of data to two arbitrary parameters does create a better "fit" to the data for molecules within a group but is much worse when one tries to fit all molecules to a single straight line.

The data indicate that it is possible to employ the usual mathematical techniques of obtaining a better "fit" to the data with an increased number of arbitrary parameters, within groupings of molecules. These data and those of the preceding columns also seem to indicate that one cannot obtain a good "fit" to both groupings of molecules and to all molecules at the same time. In fact, these results lead to a generalization of Varshni's (1957) statement that "there are no 'universal' relations connecting α_e and $\omega_e x_e$ with Δ" (the Sutherland parameter involving k_e, r_e, and D_e).

A second method of introducing a second arbitrary parameter was shown by Badger (1934) and Sutherland (1940). A term $(r\text{-}d)$ is used in their empirical relations where d is an arbitrary parameter. (There is some indication that this distance parameter may be correlated to the row of the Periodic

Table to which the constituent atoms of the diatom belong). Frost and Musulin (1954b) have also obtained relations introducing a second arbitrary parameter in this manner. Again the use of a second arbitrary parameter improves the "fit" within groupings of molecules, but this method of introducing the second parameter appears to also improve the "fit" for all molecules (Frost and Musulin, 1954b).

Two New Empirical Relations

Frost and Musulin (1954b) derived two new constants L and M, related to the third and fourth derivatives of the potential energy curve (and hence to α_e and $\omega_e x_e$, respectively). If one allows the second arbitrary parameter (the distance parameter) to go to zero in the expressions of L and M of Frost and Musulin (1954b), the following relations may be derived:

$$L' = \frac{\alpha_e \omega_e}{B_e^2}$$

$$M' = \frac{\omega_e x_e}{B_e}$$

where ω_e is the fundamental frequency, L' and M' are constants, and the other symbols have the significance previously given.

Since these are first order approximations, one would expect them to be less valid for all molecules. The preceding analysis would indicate that there might be an expectation that L' and M' would yield relations which would be consistent within certain groupings of molecules but not as good for all molecules. The deviations of L' and M' from constants in Table 1 do indicate that this is the case. These two new constants should prove useful in predicting values of α_e or ω_e and $\omega_e x_e$, although the relations would not be expected to hold for all molecules or for all states of a single molecule. The "fit" for all molecules is surprisingly good when compared to the other data in Table 1. M' does not appear to be as consistent as L', but this is not surprising when one considers that successive derivatives of the potential energy curve are more sensitive to errors (Frost and Musulin, 1954b).

Table 2 gives a comparison of the "fit" of L' and M' compared to L and M for the molecules given in the paper of Frost and Musulin (1954b). This table indicates that the first order approximations are not as good when considering all molecules, but in some instances the fortuitous compensations do give better "fits" within groupings of molecules.

Table 2.—Comparison of Average Percentage Deviations.

Molecular groupings	—L	—L′	M	M′
Group IA-Group IA	7	9	42	20
Group IIB-hydride	1	17	15	28
Group VIIA-Group VIIA	7	8	18	10
All molecules	12	31	42	39

An interesting aspect of these calculations is that the various empirical relations seem to be particularly valid, in many instances, in a given period of the Periodic Table. That relations of this type hold in periods, for polyatomic molecules, has been shown recently by Heath, *et al.* (1950).

Summary

An equation giving a good representation of the potential energy curve does not necessarily provide a good relation between spectroscopic constants. In fact, it appears that a "good" relation between these constants occurs only because of the cancellation of variation in the constants. The usual mathematical methods of providing a better "fit" to a set of experimental data does lead to relations which are very useful for predicting values of unknown spectroscopic constants. This gain in usefulness is made only at the expense of losing a relation which will fit all molecules. This reasoning is used to derive two new relations useful in predicting the values of α_e or ω_e, and $\omega_e x_e$.

The use of empirical constants will continue to be useful to estimate spectroscopic constants in diatomic molecules and polyatomic molecules, but it does not seem possible to relate the varied spectroscopic behavior of many molecules or to ascertain by semi-empirical or mathematical analysis whether a given relation will be more useful than another.

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DROSOPHILA OF THE MONTGOMERY ARBORETUM, ILLINOIS

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A study of wild *Drosophila* of the Montgomery Arboretum, DeKalb County, Illinois, was undertaken to determine the species present and their relative abundance.

Two collecting sites were established in the Arboretum, which is a "mixed deciduous mesophytic" forest. Along the northern margin of the Arboretum is a small stream that flows in an easterly direction. On the south side of this stream is a flood-plain approximately 12 feet wide. Collecting site No. 1 was located about 100 feet west from the eastern end of the Arboretum and about 8 feet from the stream. Within a 15-foot radius of this site the dominant type of vegetation is basswood (*Tilia americana*), hawthorn (*Crataegus* sp.), members of the mint family *Labiatae*, and various members of the grass family *Graminae*.

Collecting site No. 2 was located in the southwest corner of the Arboretum, approximately 150 feet from the bisection of Lincoln highway and Normal road. Here, the vegetation was fairly dense and afforded protection from wind and sun. The predominant form of vegetation within a 15-foot radius of the site appeared to be black cherry (*Prunus serotina*), buckthorn (*Rhamnus caroliniana*) and wild geranium (*Geranium maculatum*).

Methods

Mashed and fermenting bananas were used as bait, set out in five-gallon cans fitted with covers which were held slightly off the tops of the cans. This gave the flies free access to the food and protected the bait from inclement weather. Collections were made at both sites, approximately at sunset from May 17 through July 8, 1959. Identifications were made from Sturtevant's key (1942).

Results

A total of 2,065 flies was examined from site No. 1, of which 1,925 or 93% were members of the *D. affinis* species group. Next most frequent was *D. robusta* with 77, or 3.7%. The other species found were: *D. melanogaster*, 27 or about 1%; *D. melanderi*, 19; *D. putrida*, 10; *D. transversa*, 5; and *D. buskii*, 2%.

At site No. 2, a total of 2,028 flies was examined; 1,851 or 91% belonged to the *D. affinis* species group. The next most numerous was *D. robusta* with 82, or 4% of the total. Other species found were: *D. melanogaster*, 59, or about 3%; *D. transversa*, 21; *D. immigrans*, 5; *D. putrida*, 4; *D. melanderi*, 3; *D. tripunctata*, 2; and *D. buschii*, 1%.

Discussion

Although *Drosophila* is best known for its use in studies of problems of heredity, it has of recent years become important in investigations of organic evolution through genetic studies of wild populations (Spencer, 1950). However, as a

first step in studies of wild populations, it is necessary to determine species present and ways to collect them.

From June, 1938, through October, 1942, J. T. Patterson made extensive collections of *Drosophila*, primarily in southwestern United States. He made only scattered collections in the South and Midwest; the only state in the Midwest included in his collection records is Ohio. Patterson's list of species for Ohio contains 32 species found throughout that state. This includes six species Spencer found near Wooster, Ohio. Of the nine species identified in the Montgomery Arboretum, eight are found in Ohio.

Further details of site and methods and a more extended discussion are available in Knez (1959).

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POPULATION RELATIONSHIPS OF SPIDER MITES AND TYPHLODROMID MITES ON APPLE TREES IN CENTRAL ILLINOIS

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Much controversy exists on the importance of species of typhlodromid mites (family Phytoseiidae) as predators of spider mites (Beglarov, 1957; Collyer, 1956; Clancy and Pollard, 1952; Huffaker, 1958; Lord, 1949 and 1956; Marshal and Morgan, 1956; and many others). Interactions between spider mites, their predators, and their environments are extremely complex. It is the purpose of this paper to present a few observations on the densities of spider mites and typhlodromid mites found on apple trees.

Methods

Henderson and McBurnie (1943) designed a brushing machine which has proved highly successful for rapidly estimating spider populations. Morgan *et al.* (1955) found that this machine removed 100% of the active stages and 98.8% of the eggs of spider mites on leaves of Delicious apple trees. Morgan *et al.* reported the same efficiency in the removal of eggs and active stages of typhlodromid mites and other predaceous mites. In every case they found more typhlodromid mite eggs by using the Henderson and McBurnie brushing procedure than were recorded by direct observation with the aid of a microscope.

I have used the Henderson and McBurnie brushing machine procedure since 1953 and have found it satisfactory for estimating spider mite populations; however, typhlodromid mites move more rapidly and are more easily disturbed by light and jarring than are spider mites. These factors reduce the effectiveness of the brushing machine procedure for estimating populations of typhlodromid mites. Often direct counts gave population estimates several times higher than the brushing machine procedure. In this study I have, therefore, used the more direct method of hand picking the leaves and counting the numbers of mites present on the leaves, with the aid of a microscope.

During the spring and summer of 1954, 1955, 1956, and 1957, samples were collected at intervals of about one week from three lots of Jonathan apple trees at Urbana, Illinois. Each lot consisted of four trees of nearly the same age and size. The samples consisted of 25 leaves picked at random from each tree in each lot. The 100 leaves from each lot were put in a plastic bag and taken to the laboratory where the mites were counted within 30 minutes after sampling time.

The first lot of trees received no chemical treatment during the four years of the study and presumably in years preceding the study. These trees will be referred to as "unsprayed".

The second lot of trees was incidentally sprayed with DDT in the course of a Dutch elm disease control program. This program started

in 1949 with two foliar applications of 6% DDT with a mist blower and continued until 1954 when a 12% DDT prefoliar treatment was substituted for one of the foliar treatments. In 1955, 1956, and 1957, only a 12% DDT prefoliar spray was used. The apple trees in this lot will be referred to as "D D T treated".

Although there was year-to-year variation, the third lot of trees received treatments on approximately the following schedule each of the four years of the study:

Dormant: DN 289, 2 qts. per 100 gals. water.

Prepink: (about April 20-30) lime sulfur, 2.5 gals., or organic mercury according to directions on the label, plus microfine sulfur, 4 lbs., or Vancide M, 2 lbs. per 100 gals. water.

Pink: (about first week in May) 2 lbs. lead arsenate, 2 lbs. Vancide M or 3 lbs. microfine sulfur and 1 lb. additional fungicide.

Calyx: (in mid-May) lime sulfur 2.5 gals. per 100 gals. water. 6 or 7 Cover Sprays: (ending in August) 2 lbs. DDT 50% W.P., 2 lbs. lead arsenate (stopped in June) various fungicides, and 2 lbs. malathion 25% W.P. per 100 gals. water.

These trees will be referred to as receiving a "recommended control program".

Observations on Predators

Typhlodromus pomi (Parrott) and *T. rhenanus* (Ouds.) appear to be the most important spider mite predators on apple trees in central Illinois. About 91% of the predators on the unsprayed trees were *T. rhenanus*, about 60 % on the DDT treated trees were *T. pomi*, and about 38% of the predators on the trees receiving a recommended control program were *T. pomi*. The other observed predators were: a snout mite, *Bdella depressa* Ewing; an undetermined mite belonging to the family Raphignathidae; a thrip, *Scolothrips pallidus* (Beach); an aphis-lion, *Chrysopa* sp.; and four species of ladybird beetles, *Adalia bipunctata* (L.), *Cycloneda munda* (Say), *Hippodamia convergens* Guer., and *Stethorus punctum* (Lec.).

Population Relationships

Figure 1 shows the number of *Typhlodromus rhenanus* and the total number of spider mites per 100 leaves on the samples from the unsprayed trees for the four seasons. In 1954, 1956, and 1957, spider mites were not found until July or August, and did not become abundant enough to cause damage. In 1955, spider mites were present in June and became abundant enough to cause damage during July. During the three years in which no spider mite damage occurred, *T. rhenanus* was collected before the spider mites appeared and was present in about a one to one predator-prey ratio. In 1955, when the spider mite damage occurred, the spider mites got the jump on the predaceous mite in June. However, *T. rhenanus* became abundant about two weeks later and the spider mite population dropped rapidly. Thus it seems there is a relationship between low spider mite populations and the presence of *T. rhenanus*. The only species of spider mite occurring on the unsprayed trees was the two-spotted spider

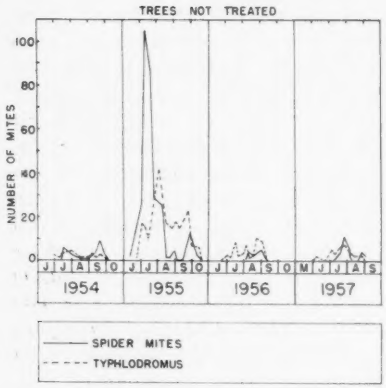

FIG. 1.—Number of spider mites and typhlodromid mites per sample of 100 apple leaves on untreated trees.

mite, *Tetranychus telarius* (L). It comprised 41.4% of the mite population for the four years; the rest of the mites were *Typhlodromus rhenanus*.

Figure 2 shows the number of *T. pomi* and the total number of spider mites per 100 leaves on the samples from the DDT-treated trees for the four seasons. In all four seasons the spider mites caused serious injury to these trees. This was evidenced by bleached appearing leaves and by spots and streaks of dead leaf tissue. Most of the damage was caused by the clover mite early in the season. In August and September of all four years, the two-spotted spider mite became abundant enough to cause injury. The clover mite, *Bryobia praetiosa* Koch, made up 87.3%, the two-spotted spider mite 7.9%, the European red mite, *Panoychus ulmi* (Koch), 0.2%, and *T. pomi* 4.6% of the total four-year population of these species. The ratio of *T. pomi* to spider mites was about 1:27 on the DDT-treated trees.

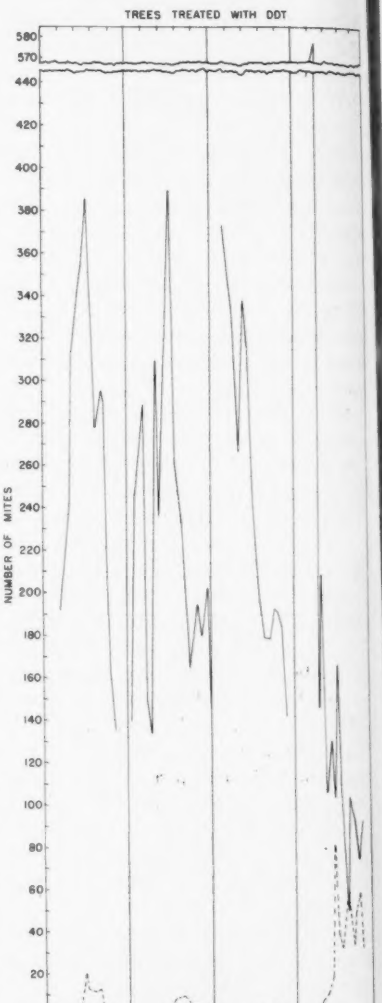

FIG. 2.—Number of spider mites and typhlodromid mites per sample of 100 apple leaves on trees treated with DDT.

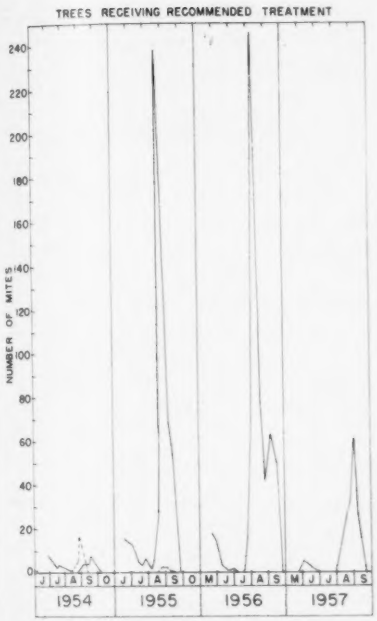

FIG. 3.—Number of spider mites and typhlodromid mites per sample of 100 leaves on trees treated with a recommended orchard spray program, including DDT and malathion.

Figure 3 shows the number of *T. pomi* and the total number of spider mites per sample of 100 leaves on the trees managed under a recommended control program for four years. In 1956 and 1957 no *T. pomi* were collected on these trees. In 1955 and 1956 the two-spotted spider mite caused injury in August and September. Under this control program, 77.2% of the total number of mites present were the two-spotted spider mites, 11.5% clover mites, 8.9% European red mites, and only 2.4% were *T. pomi*. The ratio of *T. pomi* to spider mites was about 1:44 on these trees.

Effects of Spider Mites on Fruit Yields

The average annual yield of fruit was estimated to be 0 to 0.25 bushels per tree on the unsprayed trees, 0.25 to 2 bushels per tree on the DDT-treated trees, and 2 to 5 bushels per tree under a recommended control program. The quality of fruit was superior under the recommended control program, because of less disease and insect damage.

Discussion

On apple trees that had no chemical treatment, spider mites were not abundant enough to cause damage, except on one occasion. In the absence of chemical treatment, *T. rhenanus* appears to be an effective predator of the two-spotted spider mite, *Tetranychus telarius*. On the trees treated with DDT, the clover mite, *Bryobia praetiosa*, was a serious problem in the spring, and the two-spotted spider mite was a problem during the summer. On the trees receiving recommended treatment, spider mite damage occurred during the last half of the season in two years and was for the most part caused by the two-spotted spider mite. The clover mite and the European red mite appeared as potential problems, but caused little damage. On the DDT-treated trees and on trees receiving a recommended treatment, the principal predator was *Typhlodromus pomi*, rather than *T. rhenanus* as on the trees receiving no chemical treatment.

Ristich (1956) reported complete or nearly complete kills of *T. fallacis* (Garm.) with DDT, parathion, chlorobenzilate, Systox, lindane, tox-

aphene, Ovex, heptachlor, dieldrin, and malathion. Huffaker and Kennett (1953) found that Systox, TEPP, parathion and Ovotran were harmful to *T. reticulatus* Ouds. I have also found aramite, malathion, and DDT harmful to typhlodromid mites. Huffaker and Kennett further reported that in their parathion-treated strawberry plots, *T. reticulatus*, a very effective predator of the cyclamen mite (*Tarsonemus pallidus* Banks), was replaced by *Typhlodromus occidentalis* Ouds., a parathion-tolerant predatory mite. *T. occidentalis* was found to be a less effective predator of the cyclamen mite than *T. reticulatus*. It seems that a parallel case occurs on the apple trees which I have studied. *T. rhenanus* appears to be an effective predator of spider mites, but appears to be eliminated by chemical treatment. *T. pomi* seems to be more tolerant of chemical treatment, but is a poorer predator than *T. rhenanus*.

Summary

These observations indicate that predation by *Typhlodromus rhenanus* has a deterrent action on the development of infestations by spider mites. Chemical treatments tend to change the proportional relationships of typhlodromid mites to prey species, the species of typhlodromid mites present, and the proportional relationships of typhlodromid mites to other predators. The replacement of *T. rhenanus* by *T. pomi* results in greater spider mite damage or a greater potential toward spider mite damage on the chemically treated trees. The advantage of natural control, however, is outweighed by the production of more and better fruit with a satisfactory spray program.

Acknowledgments

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NOTES ON THE ECOLOGY OF MAMMALS OF A STRIP-MINED AREA IN SOUTHERN ILLINOIS

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Where lands are progressively laid bare by strip-mining, observations of changes of habitat and responses of animals become possible on a scale not often available to ecologists and provide a ready means of obtaining data useful in understanding faunal distribution. Nevertheless the ecology of striplands has not been studied extensively. Often they are not within easy distance of interested students.

The revegetation of such areas in southern Illinois has been described by Bell (1956:85-91) and Brewer and Triner (1956:73-84), and that of other Illinois strip-mined areas by McDougall (1925:378) and Croxton (1928:158). The invertebrates of several selected communities were studied by Smith (1928:493). Yeager (1942: 619) recognized that invasion of striplands by mammals was related to the age of the areas since mining. Brewer (1958:544) found no significant correlation between the age of stripped area and species of birds breeding there. He believed that "local variation in vegetation may have been most important in determining density." In a study of the distribution of *Peromyscus leucopus* ssp. and *P. maniculatus bairdi*, Verts (1957:56) found that *P. leucopus* ssp. preferred older strip-mined areas and *P. m. bairdi* preferred more recently mined areas. In Ohio, Riley (1954:324) compared wildlife populations on strip-mined land with those on various types of agricultural land. Lewis and Peters (1955: 117-124) reported on the physicochemical characteristics of stripland ponds in southern Illinois.

As part of an investigation to determine the wildlife potential of coal strip-mined lands in southern Illinois, an ecological study of the mammalian fauna was conducted. The study was started August 4, 1954, and terminated May 30, 1956. Distribution and populations of mammals as related to the age of strip-mined areas, vegetative composition, and topography were aspects most intensively investigated.

Description of the Area

The 1,792-acre research area is located in Perry County, about 5 miles south of Pinckneyville and 2 miles west of Pyatts, Illinois. Southern Illinois University holds title to the western 920 acres, and the remaining 872 acres is owned by Truax-Traer Coal Company.

Strip-mining operations began on this land in 1932 and continued until 1950, with the exception of 1934. The study area, therefore, contains 18 areas which vary in age from 6 to 24 years. The acreage, direction of stripping, and shape of these tracts are not uniform. There are also several unmined areas which vary in size from 4 to 51 acres and total approximately 154 acres.

Topographic, soil, and vegetative characteristics of this area have been previously described (Verts, 1957: 53). In general, there were few

differences in vegetative composition between the oldest and the most recently mined areas. The only major difference in vegetative characteristics was an increase in diameter and height of trees corresponding to an increase in time elapsed since mining.

Materials and Methods

Techniques used in small-mammal censusing were as follows: 30 to 50 stations were established in lines at about 10-yard intervals and 2 museum-special or ordinary mouse traps, baited with a mixture of peanut butter, oatmeal, and DDT, were set within a 3-foot radius of each station marker. Traplines of this type were operated for two consecutive nights in a strip-mined area of each age in late summer and early autumn of 1954 and late winter and early spring of 1955.

Distribution and relative abundance of larger mammals were determined by observing sign (tracks, scats, cuttings, and dens) and individuals. As this area was open to public hunting and trapping, an index by use of questionnaires was made of numbers of game and fur mammals removed.

A representative collection of stripland mammals was desposited in the Cooperative Wildlife Research collection of Southern Illinois University.

Nomenclature of mammals used in this paper is that of Miller and Kellogg (1955).

Accounts of Species

Didelphis marsupialis **Kerr. Opossum. Tracks and scats indicated relatively uniform distribution. In autumn of 1954, sign was found on almost every spoil pile, but by autumn of 1955 was much reduced. Three specimens collected; none by hunters and trappers.**

Blarina brevicauda **(Say). Short-tailed shrew. One taken in black locust plantation, strip-mined in 1939.**

Cryptotis parva **(Say). Least shrew. Skull found in area strip-mined in 1944.**

Scalopus aquaticus **(Linnaeus). Eastern mole. As indicated by extent of runways, found to be restricted usually to moist sites between spoil piles and in unmined areas. In periods of heavy precipitation, runways were more extensive and occasionally crossed crests of spoil piles. Two collected.**

Pipistrellus subflavus **(F. Cuvier). Eastern pipistrelle. Six shot near unmined woodlands on west edge of study area. Pipistrelles probably use area only to feed and drink; sites favored for roosting (Hamilton, 1943:86) relatively few.**

Lasiurus borealis **(Müller). Red bat. Five taken in same locality as pipistrelles. Probably feeds and drinks on area but roosts elsewhere.**

Sylvilagus floridanus **(J. A. Allen). Cottontail rabbit. Populations determined by counting groups of droppings (pellets) in 4- by 100- foot quadrats. Ten quadrats established in strip-mined areas of each age, with approximately equal numbers on spoil-crests, slopes, and in valleys. As indicated by mean number of piles of pellets per quadrat, cottontails occurred throughout area, but most abundantly in more recently mined areas, especially in tracts mined in 1947, 1948, and 1949.**

Cottontail populations apparently not correlated with height, density, or composition of vegetation, except in dense pine plantations where sign was rarely observed.

Hunter-success reports indicated that 138 (0.74 per hunter-hour) and 141 (0.53 per hunter-hour) cottontails were harvested in the 1954-1955 and 1955-1956 hunting seasons, respectively. Pellet counts indicated a population decline of similar magnitude.

Marmota monax **(Linnaeus). Woodchuck. Active dens observed in strip-mined areas of all ages. No apparent correlation between numbers of den sites and age of strip-mined areas. Concentrations of burrows in unshaded rocky areas supporting dense stands of sweet clover.**

Tamias striatus **(Linnaeus). Eastern chipmunk. Nine taken in autumn of**

1954 near west edge of study area. Although all activity was noted within 50 yards of unmined woodlands, two animals had burrows in spoil piles. Repeated hunting and trapping in 1955 produced no chipmunks.

Sciurus carolinensis Gmelin. Gray squirrel. Individuals noted on several occasions on unmined portions of study area; it may be assumed that they ranged short distances into spoil piles. Lack of mature forest and mast-producing trees probably exclude this species.

Sciurus niger Linnaeus. Fox squirrel. None observed on striplands, but leaf nests containing fur of fox squirrels were found in areas strip-mined in 1932, 1933, 1943, and 1945, and in several unmined tracts. Low density of woodlands and lack of mast-producing trees probably limit this species.

Glaucomys volans (Linnaeus). Southern flying squirrel. Evidence was fur left in rat trap nailed to large tree near west edge of area. Limiting factors probably same as those listed for tree squirrels.

Castor canadensis Kuhl. Beaver. Cuttings indicate periodic use of some stripland ponds. Evidence of heavy beaver activity previous to this investigation was noted in one pond. A freshly cut cottonwood was found in small pond nearby in May, 1955, but repeated observations revealed no additional sign. An insufficient food supply probably limits this species.

Peromyscus leucopus (Rafinesque). White-footed mouse. Taken in strip-mined areas of all ages, this was predominate species of *Peromyscus* in older tracts, and was only *Peromyscus* taken in areas strip-mined in 1932, 1933, 1935, and 1939. Three hundred sixteen taken in 6,221 trap-nights from August, 1954, to May, 1955.

Peromyscus maniculatus (Wagner). Deer mouse. Taken in areas of all ages except those mined in 1932, 1933, 1935, and 1939. Predominate species of *Peromyscus* and attained highest population levels in more recently strip-mined areas (Verts, 1957:56). Four hundred twenty-seven taken in 6,221 trap-nights from August, 1954, to May, 1955.

Pedomys ochrogaster (Wagner). Prairie vole. Taken in all areas except those mined in 1937, 1938, 1939, 1941, 1942, and 1945. Usually associated with large areas of cheat and bluegrass, but, in winter, runways found beneath fallen sweet clover stems. Only 32 taken in 6,221 trap-nights; eight in 400 trap nights in the area strip-mined in 194

Ondatra zibethicus (Linnaeus). Muskrat. Populations indexed by recording numbers of cuttings, den entrances, and scats in ponds easily accessible by boat. Activity noted in almost every pond of sufficient depth to retain water throughout year but was relatively more intense in smaller ponds.

Definite correlation noted between quantity of muskrat sign and character of shoreline soils. Little muskrat activity noted in ponds with high proportion of rock and shale to clay in their banks. Banks which facilitated tunneling apparently essential as water depth usually too great and aquatic vegetation too limited to allow construction of houses.

Trappers reported taking 7 and 102 muskrats in the 1954-1955 and 1955-1956 seasons, respectively. Improved reporting system in 1955-1956 season was undoubtedly responsible for most of difference between two years.

Mus musculus Linnaeus. House mouse. Seventeen taken in spring of 1955 in areas mined in 1940, 1943, 1947, 1949, and 1950. Habitat near water apparently preferred as most specimens taken within 25 yards of pond.

Canis latrans Say. Coyote. Similiarity between coyote and dog sign made study difficult, but tracks found in areas mined in 1932, 1933, 1947, and 1950 were believed those of coyotes. In December, 1954, adult female trapped in tract mined in 1950. Farmers and hunters reported two "wolves" nearby.

Vulpes fulva (Desmarest). Red fox. Tracks rarely observed, but when found, usually in the same locations as those of gray foxes. None seen, but skull found in area mined in 1932.

Urocyon cinereoargenteus (Schreber). Gray fox. Tracks found in strip-mined areas of all ages. In general, numbers of tracks observed greater in 1955 than in 1954. Increase attributed, in part, to additional roads on area, thus increasing opportunity to observe sign. Several gray foxes flushed, but none taken.

Procyon lotor (Linnaeus). Raccoon. As indicated by sign, raccoons more or less uniformly distributed, but greatest activity noted at edges of ponds and along roadsides. Apparently most raccoons were ground dwellers.

Trappers and hunters reported taking none in 1954-1955 season and 17 in 1955-1956 season. According to reports, night hunting with dogs not productive on

striplands as raccoons habitually entered ground dens. Two collected.

Mustela frenata Lichtenstein. Long-tailed weasel. Sign noted in areas strip-mined in 1932, 1933, and 1936 where temporary ponds were surrounded by heavy growths of sandbar willow. Tracks in snow in January, 1956, were especially numerous in area mined in 1932.

Mustela vison Schreber. Mink. Sign found near seven of larger ponds. In general, more sign was observed in autumn of 1954 than in 1955. Trappers reported taking two and five in 1954-1955 and 1955-1956 seasons, respectively.

Mephitis mephitis (Schreber). Striped skunk. Sign rarely observed in autumn 1954; believed that striplands did not provide suitable habitat. In summer of 1955 sign more abundant, and skunks commonly observed in early morning or late evening. Some seen in 1932, 1933, 1936, 1945, and 1946 strip-mined areas, and tracks were seen in all areas.

Odocoileus virginianus (Zimmermann). White-tailed deer. Except for one animal flushed in September, 1954, in area mined in 1932, no evidence of deer was noted. Residents near area reported observing deer on striplands.

Discussion

The mammalian fauna of the striplands may be divided into four ecological groups: 1) Species becoming established in older strip-mined area; 2) Species distributed throughout striplands; 3) Species which apparently invade striplands soon after mining and are absent or reduced in numbers in older strip-mined areas; and 4) Species whose distribution is dependent on special conditions prevailing in localized areas on striplands.

In the first group may be placed the short-tailed shrew, eastern pipistrelle, red bat, chipmunk, gray squirrel, fox squirrel, flying squirrel, white-footed mouse, long-tailed weasel, and white-tailed deer. These species may, in general, be classified as woodland forms, or at least associated with woodlands. Plantation-type tree plantings (except pine plantings) in some of the older strip-mined areas probably are materially aiding invasion by woodland species.

Mammals more or less uniformly distributed throughout the striplands are the opossum, cottontail rabbit, woodchuck, coyote, red fox, gray fox, raccoon, and striped skunk. Most of these can be found in a wide variety of habitats, and cannot be classified as species associated with preference for specific vegetative types. It is possible that the general uniformity of vegetative cover is responsible for wide distribution of these forms on the striplands.

The only mammal which apparently invades striplands soon after mining and then is eliminated by changes associated with increased age of strip-mined areas is the deer mouse. Undoubtedly, other species will exhibit this same tendency, but length of time since mining is not sufficient for many such changes to be evident.

Mammals limited in distribution by special factors are the eastern mole, beaver, prairie vole, muskrat, house mouse, and mink. Except for the prairie vole, quantity and presence of water are apparently limiting. This species was usually found in areas which supported heavy growths of grasses. The beaver, muskrat, and mink are predominately aquatic forms and were associated with permanent water. Within this special habitat, soil composition further limited the muskrat. The house mouse and eastern mole tended to be associated with moist soils.

These ecological groups, except the latter one, appear to be seral stages in a succession toward a forest type fauna. Although there were no measurable differences in species composition of the vegetation which could be interpreted as succession toward a forest climax, slight changes in light intensity, relative humidity, temperature, wind velocity, and surface litter due to greater height and canopy size of trees in older strip-mined areas may have been sufficient to initiate changes in faunal distribution. Herbaceous composition will probably show greater responses in the future to the physical changes caused by greater height and canopy size of trees.

Summary

Mammals of a southern Illinois strip-mined area were studied with emphasis on factors which limit distribution of various species on such lands. The area contained 18 tracts mined in various years from 1932 to 1950, excluding 1934.

The only observable major difference in vegetation was increased height and diameter of trees on older strip-mined areas. Species composition or number of stems of herbaceous vegetation were not significantly different between areas of different age.

Evidence of 26 species of mammals was found on the area.

Stripland mammals were divided into four ecological groups: those becoming established on older strip-mined land, those established on more recently mined land but absent or scarce in older areas, species distributed throughout the area, and species limited by some special factor to a localized habitat.

Changes in the physical conditions due to increased height and canopy size of trees may be sufficient to initiate changes in mammal distribution.

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APPLIED SCIENCE AND THE CLASSICS—FULL CIRCLE IN A CENTURY

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In Illinois a century ago, research in applied science—research formalized to the extent of being recorded in print—was just getting under way. The time was one of rapidly expanding agriculture, hordes of hungry insects, and distressed and vocal farmers. Because this research came in answer to the needs of the time, most of it was biological.

Making known the results of scientific research was then, as now, a major problem. Of the few technical journals then in existence in North America, most were published on the distant Atlantic seaboard.

Organization of the Illinois State Agricultural Society in 1853 and the Illinois State Horticultural Society in 1856 opened to Illinois biologists of the mid-nineteenth century two important publication outlets. The transactions of these societies carried many well-written papers based on careful observation, experiment, and study. Subjects of papers included the origin and character of prairie soils; birds of Illinois most interesting to the agriculturist; strawberry culture on the prairies; cultivation, use, and value of the osage orange hedge; tree culture on the prairies; and the education of farmers' daughters.

Founding of the Illinois Natural History Society in 1858 gave biologists of the state still other opportunities for making known results of their research. At annual meetings of the society, well-conceived papers on biology were read, and most of them were later published.

Previous to 1853, the *Prairie Farmer*, founded in Chicago 12 years earlier, was the principal publication outlet for Illinois biologists. Although this periodical was frankly slanted toward the practical tiller of the soil, it regularly published technical reports by well-trained, even though largely self-trained, scientists. The high quality of these reports was in contrast to the character of some of the articles by farmer-readers with less exacting standards of research; in those days every farmer was his own agricultural experiment station.

Prominent among Illinois biologists of mid-nineteenth century—men who stressed the application of science—were John A. Kennicott, a physician, school teacher, and horticulturist; William Le Baron, physician, ornithologist, and entomologist; Cyrus Thomas, lawyer, preacher, teacher, mammalogist, and entomologist; Jonathan Baldwin Turner, college professor, horticulturist, and espouser of causes; Benjamin Dann Walsh, classical scholar, farmer, lumberman, and entomologist.

Applied biological research of the time took mainly two courses: 1) propagation of varieties of plants adaptable to the prairie soils; and 2) attempts to reduce the numbers of insects that with frustrating regularity ruined the crops.

With the opening of the Illinois country to settlement had come travelers or pioneer residents interested

in naming the plants and animals. Although interest in systematics continued, by 1860 the emphasis in most biological research had become principally utilitarian.

Many individuals contributed to this change. In response to needs of the time, they shifted the emphasis to life history studies that had direct bearing on the control of noxious insects, to the breeding and culture of plants, and to other studies that promised to make life pleasanter on the prairies. They employed trial and error techniques that by present standards would be considered clumsy and crude. However, they were scrupulous observers and prodigious workers who had no fear of new ideas. Among their written records are to be found scientific concepts that seem modern even today.

For example, they were aware that catastrophic environmental changes may be caused by man. Nearly 100 years ago, Walsh (1861:339) wrote: "Now it is universally the case, that whenever man, by his artificial arrangements, violates great natural laws, unless by some artificial means he can restore the overturned balance, he pays the penalty affixed to his offense."

Illinois biologists of a century ago were aware that man possesses possibilities of controlling nature through nature—that injurious insects can be controlled by natural agents, not only by birds but by other insects. Walsh (1861:340-341) advised his readers that "one of the most effective means of controlling noxious insects is to be found in the artificial propagation of such cannibal species as are naturally designed to prey on them," and that, so far as he was aware, "cannibal insects have never yet been bred for utilitarian purposes, yet it is by no means an uncommon practice to collect such as are found at large in the woods and fields, and apply them to subdue some particular insect that is annoying us."

The mid-century effort to make science practical, to bring it to the level of people who could make immediate use of it, was not an isolated movement. It abetted and was abetted by the crusade for industrial education. A number of individuals active in one cause were involved in, or at least sympathetic toward, the other. Jonathan Baldwin Turner, dedicated leader of the industrial education movement, was a prominent member of the State Horticultural Society and first President of the Illinois Natural History Society.

In a long letter addressed to a committee representing farmers who had heard him speak at Granville, Illinois, in November, 1851, Turner outlined his plan for industrial education. Of its background he wrote (Turner, 1855:369-370): "All civilized society is, necessarily, divided into two distinct co-operative, not antagonistic classes — a small class, whose proper business it is to teach the true principles of religion, law, medicine, science, art and literature; and a much larger class, who are engaged in some form of labor in agriculture, commerce, and the arts. For the sake of convenience, we will designate the former the PROFESSIONAL, and the latter the INDUSTRIAL class; not implying that each may not be equally industrious— the

one in their intellectual, the other in their industrial pursuits."

Turner maintained that the colleges and universities of his time were designed for the professional class and he advocated the establishment of institutions of higher learning specifically adapted to the education of mechanics and farmers—the 95% of the population he thought might be included in the industrial class.

In a pamphlet entitled *The Industrial League of Illinois* (Carriel, 1911 : 115-119), Turner asked, "Can, then, no schools and no literature, suited to the peculiar wants of the industrial classes, be created by the application of science to their pursuits? Has God so made the world that peculiar schools, peculiar applications of science, and a peculiar resultant literature are found indispensable to the highest success in the art of killing men, in all states, while nothing of the kind can be based on the infinitely multifarious arts and processes of feeding, clothing, and housing them?"

He lectured and lobbied ceaselessly, until his friend Abraham Lincoln in 1862 signed the Morrill Act that provided for land grant colleges—and then until the Illinois Industrial University at Urbana, now the University of Illinois, was chartered in 1867.

In agreement with Turner in the effort to make scientific learning available to the masses, Walsh (1868 : 9), as the first State Entomologist of Illinois, wrote that his annual report for 1867 was "intended chiefly for the use of common folks."

Walsh (1868 : 10) wrote further, "If there is one thing which I have at heart more than another, it is to popularize Science—to bring her down from the awkward high stilts on which she is ordinarily paraded before the world—to show how sweet and attractive she is when the frozen crust, in which she is usually enveloped, is thawed away by the warm breath of Nature—and more especially to demonstrate how delightful that particular branch of science [entomology], to which I have devoted half a life-time, may be to any one, who will keep his eyes wide open as he walks through his garden or his orchard."

Paradoxically, some of the most influential leaders in the industrial education movement, the effort to popularize science, and the new emphasis on applied biology had received classical educations.

Le Baron, second State Entomologist of Illinois, had been graduated from Harvard Medical College, where the classics were required subjects. Turner had taken prizes in English composition and Greek while a student at Yale College and had taught Latin and Greek at Illinois College, Jacksonville. Walsh, an Englishman, had been educated at Cambridge University, from which he had received a master's degree. As a classical scholar, he had published a work on the comedies of Aristophanes in 1837, the year before he moved to a farm in Illinois.

Probably these men could not have foreseen that, in their zeal to make science and other learning available to all, they had started a movement that too often has resulted in a type of education tending to be both narrow and shallow. Today, a century after J. B. Turner pleaded the

cause of industrial or vocational education, university and industrial leaders are taking a new look at the training of scientists.

We may doubt whether Turner would have approved of the industrial type of education many scientists now receive, for at one time he specifically included scientists in the professional class.

Pressure for a more liberal education for both scientists and engineers is coming today from many directions.

In a speech delivered in April, 1955, before the Phi Beta Kappa Association of the Chicago area, Lloyd Morey, then President of the University of Illinois, cited the results of a business survey reported in the April, 1953, issue of *Fortune* magazine; the conclusion was that overspecialization is robbing business of potential top management material. President Morey (1955: 10) added his own conclusion, that vocational education "has been accorded too significant a place in college and university programs." He said: "I do not mean to suggest that we should not teach law to the lawyers, or engineering to the engineers, or accounting to the accountants. But I would like to make them all *educated people* and not merely *technicians*."

Grayson Kirk (1959:18), President of Columbia University, wrote recently, "In the college curriculum, the task must be that of continuing for the science-motivated student his long-range interest in his field while giving him enough of a broad educational base on which to build his professional specialization."

Henry T. Heald (1957:179), President of the Ford Foundation, in addressing a group of engineers in New York City, declared, "Scientists and engineers, no less than doctors, lawyers, or the managers of industrial enterprise, need to stand as intelligent, liberally educated men, regarding their knowledge not as a narrow, isolated specialty but as a particularized competence which they, in their general wisdom, can share with the rest of society."

Nathan M. Pusey (1958:69), President of Harvard University, befor a University of California audience at Berkeley, pleaded for an acceptance by the public of "the fact that learning is apt to be most useful, even within professional schools, when it does not aim too intently or too directly at the goal of immediate utility."

Massachusetts Institute of Technology in 1953 established a department of humanities as a recognition of the need for liberal studies in a technological institution.

The Wenner-Gren Foundation, in setting up conditions for pre-doctoral fellowships in anthropology, apparently has tried to assure that students who receive grants will be well-rounded scientists. The Foundation recommends that the applicant for a grant "have a prior degree in some discipline other than anthropology, or be planning to secure such a degree, or its equivalent, in the course of his studies, and be a graduate of some institution other than the one nominating him for a Pre-Doctoral Fellowship."

In a word, the pressure from higher education and industry today is for scientists with the breadth of interests of Turner, Walsh, Le Baron, Kennicott, and Thomas.

We have now come full circle in

the education of scientists. Pressure is beginning to be felt for scientists educated as Turner, Walsh, and other early Illinois scientists had been educated—in the classics.

Werner Heisenberg (1958: 60-63), German winner of the 1932 Nobel Prize for Physics, related that as a student he improved his understanding of atomic theory through his reading, in the original Greek, of one of Plato's dialogs and he paid tribute to the influence of Greek thought upon his own thinking. Those who "wish to get to the root of things in their chosen vocation," he stated, "whether it be in technology or medicine, are bound sooner or later to encounter the sources of antiquity, and their own work can only benefit if they have learnt from the Greeks how to discipline their thoughts and how to pose questions of principle."

The plea for the classics in the education of scientists comes not alone from a theoretical physicist. It comes from — of all places — industry. T. R. Henn (1958:1325-1326), member of the faculty and an administrative officer of St. Catharine's College at Cambridge University, wrote, "Great industrial firms appear to find that, while the supply of *competent* technologists is adequate for their purposes, the supply of men for the very top posts —men who know enough science to direct research, yet whose concern is mainly with wider issues and problems of the highest magnitude —is relatively poor. Many of these firms find it profitable to select arts men — preferably, and strangely, classicists—and train them for such posts. A world-famous electrical firm has just taken seven men with first-class degrees in classics and is converting them, by an intensive three-year course, into physicists and mathematicians."

What is the explanation of this long unsuspected but now beginning-to-be-appreciated relationship between the classics and science—even applied science? Perhaps it is that scientific research— research that is to be imaginative, dynamic, and of the highest order—should be based on the postulate that man gets a longer view of Earth from Venus than he gets from Earth.

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RETAIL TRADE IN A DISPERSED CITY

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Introduction

Early work in the field of central place theory by Christaller (1933) suggested an idealized pattern of urban settlements regularly spaced in a nested hierarchy and surrounded by hexagonal tributary areas. Since that time, many other students have demonstrated the existence of a hierarchy in various parts of Europe and North America. More recently, Berry and Garrison (1958b) have shown that the concept of a threshold and the range of a good can be used to liberate theory from assumptions about even distribution of population and purchasing power over uniform topography.

It does not necessarily follow, however, that an urban hierarchy always exists. It may be, for example, that as accessibility increases, the normal hierarchy collapses and is replaced by some modified pattern. Alternatively, the hierarchy may not have an opportunity in which to develop.

Purpose

The politically discrete cities of southern Illinois have been previously referred to as a dispersed city by Beimfohr (1953), although the urbanized areas are separated in some cases by tracts of agricultural land. It is the purpose of this paper to present some aspects of the retail trade of the area and to test the hypothesis that the area functions as a single city, rather than as a number of discrete cities. From this it will be inferred that spatial propinquity is a factor tending to prevent the emergence of hierarchical patterns. The study will also try to cast some light on the nature of dispersed urban agglomerations with respect to retail trade, and to suggest a way in which these may be expected to differ from strongly nucleated urban areas.

Definitions

On the basis of traffic flow and population density the area was delimited along county lines, and includes Perry, Franklin, Jackson, and Williamson counties (Fig. 1). Within these counties lies the urban core, which is composed of 14 major centers ranging in population size from more than 11,000 to less than 2,000 persons. It is these centers which would normally be expected to be arranged in a hierarchy, but, as will be seen shortly, they are not so arranged.

Beyond this urban core lies a less densely populated area, forming a situation which is taken to correspond to that of a city surrounded by its metropolitan county area. The structure of this city (as defined in Fig. 1) includes 14 major retail shopping centers located in the scattered urban centers, none of which is clearly dominant over the remainder. One important distinction between this city and another city of comparable size is therefore immediately apparent. There is no equivalent of a "downtown" shopping district.

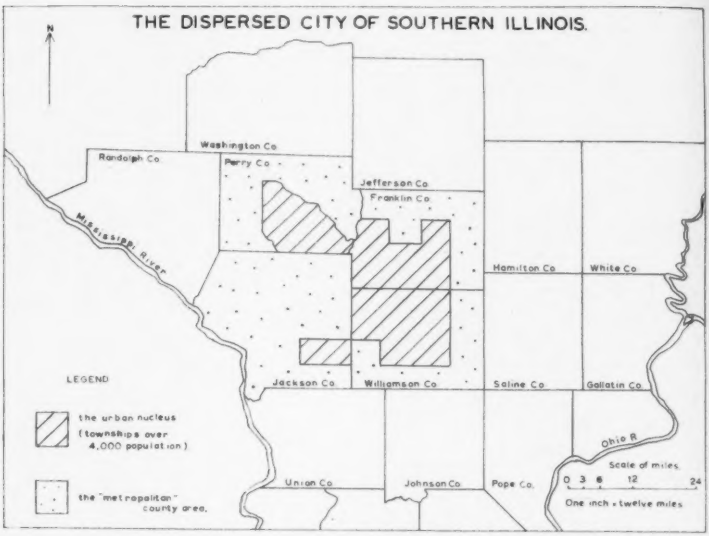

Figure 1.

The Rank-Size Rule

The unity of the dispersed city of southern Illinois is indicated by application of the Zipf rank-size rule, which has been shown to be generally valid for areas within the United States (for example, the state of Washington), as well as for the whole country. When the dispersed city of southern Illinois is placed in the rank-size curve for Illinois, a closer approximation to the ideal curve results.

Retail Trade per Capita

On the basis of previously formulated central place theory, it is known that smaller cities attract more trade from beyond their own limits, in relation to their size, than is the case in larger cities. This is one aspect of the variation of the basic-nonbasic ratio. It is to be expected therefore that, if the dispersed city of southern Illinois operates as a single city, it will have a relatively low value of retail trade per capita in common with cities of its size class. Data collected for 1955 (Sales Management) for the 30 cities in the United States of most similar size to the total population of the dispersed city, 157,000, (the 15 next smaller and the 15 next larger) demonstrate that in fact the dispersed city has an even lower value of retail trade per capita than all except three of those cities, and that it falls just within two standard deviations below the mean of their distribution.

As a confirmation of this information, the dispersed city was compared with five other cities, also created synthetically, this time by the cumu-

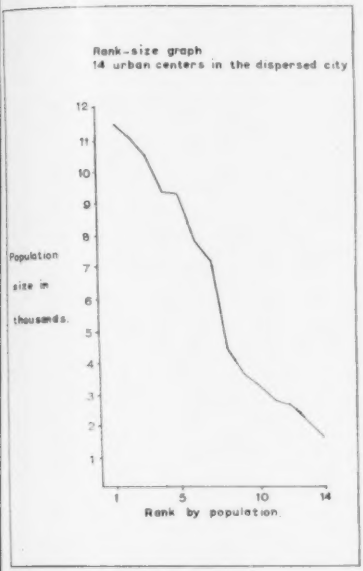

Figure 2.

lation of repetitive random samples from all cities in each synthetic city. The values of retail trade per capita, in this case, are much higher than the values for the dispersed city, which lies well outside two standard deviations from the mean of their distribution. This confirms that the cumulation of data for the southern Illinois centers, into one figure for a single dispersed city, is unlikely to have revealed by chance such low retail trade values per capita.

Percentage Sales Index

Certain assumptions involved in the fore-going paragraph, however, are not strictly valid. For example, the purchasing power of all persons is not equal, and secondly, given equal purchasing power varying amounts will be spent on retail purchases. An attempt in the direction of meeting the first objection is to consider the relationship of retail sales volume to effective buying income (E. B. I.). By calculating the former as a percentage of the latter, an index is obtained which is partly a measure of the amount of income spent on retail purchases and partly a measure of purchases made by non-residents and, therefore, of centrality.

When the index for the dispersed city is compared with the distribution of values for the 30 cities of similar size referred to above, it falls within one standard deviation of the mean, again suggesting a confirmation of the characteristics of a single large city. The second objection remains valid, that percentage of income spent on retail purchases varies from person to person and

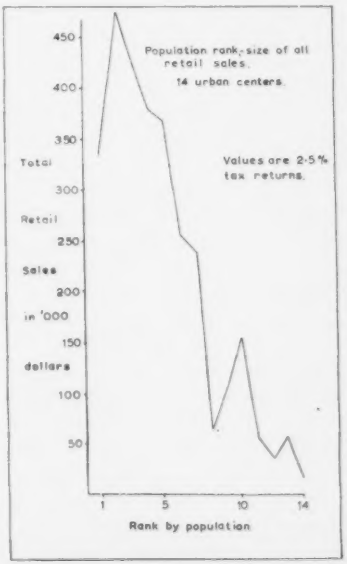

Figure 3.

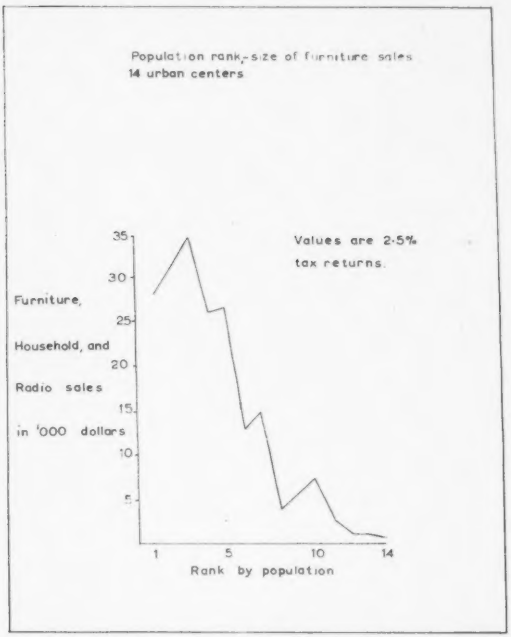

Figure 4.

from place to place. This factor is minimized by a comparison with all 66 cities of similar E. B. I. (E. B. I. of the dispered city is $193 million; similar E. B. I. is defined as ranging from $150 million to $250 million), on the assumption that expenditure on retail purchases will vary much less in each income group. The dispersed city is found to exhibit an index close to the mean of this group.

In conclusion it may be stated that evidence concerning the overall pattern of retail sales in this area has been gathered and compared against data for other cities. The results do not disprove the hypothesis that the discrete cities of southern Illinois may be regarded as a single dispersed city.

Internal Trade Patterns

It is now reasonable to question if the pattern of retail trade within the dispersed city corroborates data already discussed. The population rank-size graph for the 14 largest urban centers within the dispersed city (Fig. 2) assumes remarkably different form when population is replaced by value of retail sales. The second, third, fourth, and fifth urban centers in population rank all have a larger value of trade than the first center, West Frankfort (Fig. 3). The latter center, on the other hand, does have larger sales of furniture, household and radio goods than centers four and five (Fig. 4). Sales of general merchandise show an even more unusual pattern (Fig.

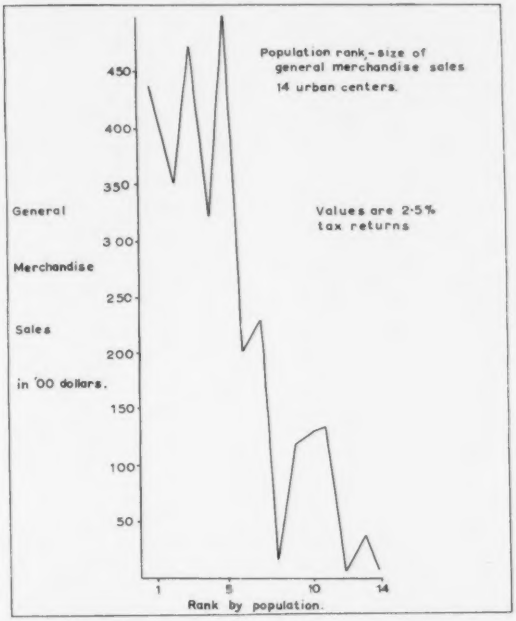

Figure 5.

5), centers two and four being much lower than centers one, three, and five. This evidence points strongly to a marked degree of local specialization in various types of retail trade among the different centers.

It seems clear that from the view point of retail trade these urban centers are not arranged in a hierarchical pattern, possibly because their very proximity to each other in an area of some 157,000 people has served to encourage local specialization rather than the domination of any one of them.

External Trade Patterns

The foregoing conclusions raise the question of the importance of a highly concentrated "downtown" shopping district. Information gathered in the dispersed city suggests that local specialization among the various centers does not completely replace the attraction of downtown shopping districts. For example, a study, by the Trades and Services Committee (1957), made in West Frankfort, the largest of the urban centers in the dispersed city, indicated that of a random sample of inhabitants interviewed 68% reported habitual purchases outside of West Frankfort. Of these, 81% reported the "outside place" to be another urban center in southern Illinois, thus demonstrating a general willingness to travel within the dispersed city to shop, a conclusion which might well have been predicted on the basis of the above anal-

ysis. It is interesting to note that the remaining 18.5% reported habitual purchases outside southern Illinois, these being distributed as follows:

St. Louis	14.1%
Chicago	2.5%
Evansville	1.9%

On the reasonable assumption that 18.5% is an unusually high figure for habitual purchases outside the city of residence, we may conclude that this dispersed city loses some of its trade to outside competitors by virtue of its lack of the equivalent of a "downtown" shopping center.

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USE OF WORLD HEALTH ORGANIZATION MOSQUITO TEST KITS WITH DDT RESISTANT DROSOPHILA

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Introduction

Widespread use of commercial insecticides in the last two decades has enhanced the development of resistance to chlorinated hydrocarbon insecticides by some important disease vectors and by a number of arthropods which are of importance to public health (Brown, 1958). In connection with this problem, the World Health Organization (W.H.O.) has undertaken the task of coordinating international research in the study of resistance to insecticides. This organization also provides a kit for investigating the resistance of mosquitoes. It also provides all the materials and instructions necessary to carry out a testing program.

The initial problem of insecticide-resistance is the determination of its existence. Probably the best method is by use of a standardized testing procedure with standardized equipment and conditions. One of the goals of the W.H.O. is to develop such a standardized test for comparison of susceptibility and resistance levels of arthropods used for genetic study. Thus, one part of this study dealt with the investigation of the value of the W.H.O. test kit as a standardized testing device for DDT resistant *Drosophila*.

Materials and Methods

Eight strains of *D. melanogaster* were used for these tests. HL 1 - Q and HL 2 - Q were representatives of sibling-selected lines with high DDT-resistance cultured by Bennett (1959). LL 1 - Q and LL 2 - P were low DDT-resistant lines selected during that same period. Cage 1, duplicate, used in this study, was descended from the original unselected wild-type progenitors of both the high and low resistant lines (Bennett, 1959). SySM 1 and ORS 1001 were DDT-resistant strains selected by King (1957) at the Cold Spring Harbor Biological Laboratory. Brown-Eye-R was a strain of DDT-resistant flies which were selected by Crow (1954) at the University of Wisconsin. It should be pointed out that a varying amount of time had elapsed between the time that these flies were originally selected for DDT-resistance and the time that the tests for this study were conducted.

The first resistance testing in this study was done in January and February, 1959, using the W.H.O. dieldrin sets. The flies were etherized and sorted to isolate females for testing purposes. One test for one stock used flies from several cultures. The use of female *D. melanogaster* tends to give more reproduceable results than those based on males (Crow, 1954). Range in age was from 24 hours to one week in most cases. This method gave results which were based on the average aged fly and probably added a greater degree of variation than would results based on flies of a specific age.

Testing methods for either the W.H.O. dieldrin or DDT sets followed this general pattern:

1. Flies of a particular stock were collected from food vials and/or bottles 12 to 24 hours prior to testing, etherized, sorted, and 25 to 30 females transferred to holding vials (this follows the recommendations for adult mosquitoes per the W.H.O. instruction booklet (W.H.O., n.d.). It was later found that this number could be increased without distorting the results.
2. Flies were incubated for a 12- to 24-hour recovery period to reduce any effects caused by etherization, which might have subsequently influenced their reaction to DDT or dieldrin.
3. The following day live, healthy flies were transferred to tubes containing insecticide for the test. During actual exposure the flies were kept in the incubator, to maintain constant conditions as closely as possible, for 1, 8, or 18 hours depending on the time required for the individual test.
4. Upon completion of exposure to insecticide, flies were returned to holding vials marked to indicate the concentration of insecticide to which the flies had been subjected. Flies were placed in and removed from the testing tubes in a serial order so that the first in were the first out. This procedure insured equal test periods.
5. Flies were returned to the incubator for a 24-hour "recovery" period. The live and dead flies were counted (flies unable to walk being considered dead), and the results recorded.

The methods used with Bennett's (1959) test sets (an alternate testing method) which were made up in June, 1958, follow closely the overall pattern used for the W.H.O. 18-hour testing program. Bennett's test sets were originally made by impregnating filter paper with acetone as the vehicle for DDT. The acetone evaporated, leaving pure DDT crystals on the paper.

In our tests, concentrations of insecticides were used which were regular multiples of the lowest concentration. This was done to make it possible to use "Karber's Method" (Cornfield and Mantel, 1950) to estimate the dose of insecticides which would kill one half of the flies represented in the population of each series of three or more concentrations (LD50).

The LD50 values for individual sets of concentrations were treated as units of data in the statistical analysis.

Results and Discussion

Dieldrin Tests.—The resistance of the strains of *D. melanogaster* to dieldrin (one hour W.H.O. test) was similar with only minor variations to the relative degree of resistance these same stocks displayed for DDT at 18 hours' exposure in Bennett's 1955-1957 study (Bennett, 1959). The stocks resistant to DDT in his study appeared resistant to dieldrin in this study, and those stocks susceptible to DDT also showed susceptibility to dieldrin. The control, Cage 1, retained a mean that was located between those of the resistant and susceptible stocks. Although these data could indicate cross-resistance of these flies to DDT and dieldrin, this phenomenon of a species being resistant to the two insecticides is not necessarily an expected result (Brown, 1958). Analysis of the results using the F test (Pearson and Bennett, 1942) indicated very little significant difference between the means of HL 1-Q and LL 1-Q flies or flies in Cage 1. By this same method of analysis, ORS-1001 showed a significant difference in its reaction to dieldrin when compared to flies in either LL 1 or Cage 1. This indicated that ORS was definitely more resistant to dieldrin

TABLE 1.—Comparison of 18-hour 0.25% DDT resistance and control testing with World Health Organization's test kits (based on percent flies killed).

Test concentration	HL 1-Q	HL 2-Q	ORS-1001	Brown-eye-R	All stocks combined
Control (oil)	100.0	100.0	27.8	100.0	.....
0.25% DDT	88.0	70.8	18.7	90.0	.....
Control (oil)	34.4	92.6	60.6	97.5	.....
0.25% DDT	33.8	50.0	57.4	89.7	.....
Control (oil)	90.5	51.7	90.0	97.7	.....
0.25% DDT	32.4	35.6	65.6	95.3	.....
Control (oil)	63.7	90.8	91.7	.....	.....
0.25% DDT	41.7	86.3	77.3	.....	.....
Average of control	75.6	85.8	61.9	98.7	81.2
Average of 0.25% DDT	49.4	62.2	57.8	90.9	66.1
Ratio $\frac{\%\text{ kill control}}{\%\text{ kill 0.25\% DDT}}$	1.532	1.379	1.071	1.086	1.227
Probability observed differences due to chance (x^2 method)	<0.001	<0.001	<0.001	$0.2>P>0.1$	.....

than were either of the susceptible lines or the control line.

DDT Tests.—Preliminary tests of one-hour duration were conducted using the W.H.O. DDT test papers. These tests produced no appreciable kill at any concentration, thus rendering them worthless as a test of DDT resistance. The instruction booklet recommends that an increase in exposure times should be the next step in such an instance. An increase to a 2-, a 4-, and if necessary to an 8-hour exposure was prescribed, but since the flies had been selected with 18-hour DDT exposures, the testing program was increased directly to 8 hours.

Results of the eight-hour W.H.O. DDT tests showed that LL 1 - Q, a susceptible stock, was most resistant. HL 1 - Q, a resistant strain, proved to be the most susceptible of all. The control, Cage 1, showed the same general range as most of the resistant stocks. Analysis (F test) of the results indicated that there were significant differences, at the 1% level, between the means for HL-1 and Cage-1 and also HL-2 and LL-1. However, some flies survived the eight-hour test at the 4.0% DDT level, so a longer exposure seemed desirable.

The 18-hour W.H.O. tests of DDT resistance produced a shifting of the relative order of the strains as to resistance, with the exception of ORS-1001 which remained fairly constant. There was a lower degree of significance in these 18-hour tests, which might have been due to the number of tests rather than to the number of flies tested. Differences between stocks tested at 8 and 18 hours were all significant

with the exception of HL 1-Q. This was unexpected because HL-1 showed the greatest resistance of all tested stocks at 18 hours and the least at 8 hours. This can be accounted for by the assumption that either there was a large genetic variation within members of this stock since resistance is determined by genetic control (Brown, 1958), or that different exposure times produced different results for the same stock. If the latter is true, and it does seem possible, the W.H.O. test kits, in order to be a standardized test device for *Drosophila*, should specify a certain period of time. This time limit could be established only after a large number of data from other research had been collected and analyzed.

A comparison was made of the 18-hour W.H.O. DDT test, the 18-hour Bennett DDT test, and an 18-hour test made by Bennett during the summer of 1958 at the University of Wisconsin. The Bennett sets used in this study were constructed and used in June, 1958. Therefore, it would be logical to assume that the test sets were more potent then than for this study, due to the volatilization of the DDT in the eight-month interim. The median lethal dose was significantly higher for the same stocks in the earlier testing program (plus some other minor variations), than it was in the tests we conducted. This would indicate a possible change in resistance between the testing dates. It is also possible that change in resistance was correlated with change from banana to cornmeal agar food. It is also possible that the conditions Bennett maintained in 1958 were enough different from the conditions in this study to cause varying results, even though the former conditions were the pattern for our testing program. Both sets of test data obtained with Bennett's test sets were vastly different from the W.H.O. test results for 18 hours, enough so that the question arises as to what stocks should be compared for relative susceptibility and resistance. Again, a greater number of tests should be conducted before this matter can be settled.

One feature is very apparent in the final analysis of the 18-hour W.H.O. DDT tests. Table 1 shows that the control paper which was impregnated with mineral oil alone produced a greater kill of *D. melanogaster* than did any test at a 0.25% DDT concentration, conducted at the same time with the same strain of flies. This difference was very significant in three of the four stocks and was prevalent in all controlled tests. Survival for the 18-hour W.H.O. test was low enough that it did not warrant testing the susceptible lines. The high percentage of kill appeared to be the result both of DDT and of the mineral oil. The oil definitely took the role of a poison or toxic substance rather than that of a neutral agent in the control experiments. We assume that there was also some effect from the oil used with the DDT, this would distort the data on the number killed by DDT alone. We feel this fact renders the W.H.O. test kit ineffective as a standardized device at 18 hours, for *Drosophila*, because it measures two different results at the same time with no discrimination. Although mineral oil did not

appear lethal in our tests at 1 or 8 hours, its effect was outstanding at 18 hours.

It is possible that HL-1 and HL-2 were resistant to DDT by behavior, in that they could recognize DDT and avoid it. Assuming this, it would then seem likely that they were unable to recognize the mineral oil as being potentially lethal, and thus did not avoid it in the control tubes. But in the 0.25% DDT tubes they may have recognized DDT and thus avoided both. This testing equipment would be improved by using a better solvent, such as acetone, which evaporates readily.

Fluctuations in temperature and humidity were occurring during the tests, and undoubtedly affected the results (Brown, 1958), although an attempt was made to regulate them. With the equipment available such errors were expected and must be considered when reviewing the results.

Acknowledgments

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Summary

1. A number of DDT resistant and susceptible strains of *Drosophila melanogaster* were tested for resistance to DDT and dieldrin, using the W.H.O. mosquito test kits. The same strains were also tested for DDT resistance by a method designed for *Drosophila*.

2. DDT and dieldrin resistance appeared to be correlated, suggesting some kind of cross reaction.

3. Apparent DDT resistance, as evidenced by ranked order of the strains, changed markedly with exposure time.

4. The mineral oil used as a carrier of insecticide in the W.H.O. test kits proved highly toxic in the 18-hour exposure tests with DDT.

5. The mosquito test kits in their present form are not suitable for use with *D. melanogaster*.

6. The most valuable aspect of the kits, for use with *D. melanogaster*, lies in the provision of standardized insecticide impregnated papers for use in equipment available locally.

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Herbert Priestley, Knox College, Galesburg.
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Russell L. Mixter, Wheaton College, Wheaton.
Dalias Price, Eastern Illinois University, Charleston.
Yale S. Sedman, Western Illinois University, Macomb.
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Robert A. Evers, State Natural History Survey, Urbana.
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John C. Frye, State Geological Survey, Urbana.
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Ralph Yeatter, State Natural History Survey, Urbana.
James S. Ayars, State Natural History Survey, Urbana.
Charles K. Hunt, University of Illinois, Chicago.
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Harlow B. Mills, State Natural History Survey, Urbana.
Lyell J. Thomas, University of Illinois, Urbana.
Milton Thompson, Illinois State Museum, Springfield.
Ralph P. Frazier, Monmouth College, Monmouth.
C. Leplie Kanatzar, MacMurray College, Jacksonville.
Wendell A. Lindbeck, Northern Illinois University, DeKalb.

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Frederick C. Holtz, Sangamo Electric Company, Springfield.
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ZOOLOGY:
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COLLEGIATE:
David Hull, 706 E. Grove Street, Bloomington.

JUNIOR ACADEMY

HIGH-SCHOOL STUDENTS CONDUCT RESEARCH

CHARLES W. OTTO and H. NEIL HARDY
Lincoln-Way Community High School, New Lenox

THE IDEA

The Phi-Chem Association is a junior-senior science club established at Lincoln-Way Community High School to promote interest and activities in science. During the past five years scientists from the Joliet area have conducted science classes, provided programs for club meetings, served as judges for science open houses, provided consultation and materials for individual student projects, served as resource persons for career selection, and conducted special field trips for selected groups of students.

At the Annual Lincoln-Way Science Open House, Phi-Chem Association members are expected to exhibit a scientific project and are encouraged to use originality in their preparation. In working with original investigations, students often enter areas in which the instructor's knowledge and experience are limited. Limited library facilities and inadequate material resources available to the students create additional problems.

Each year, as the project work improves, these problems become more acute and the need for skilled outside assistance becomes more apparent. The Board of Directors of the Association discussed the problem and considered methods of securing assistance. Suggestions considered for obtaining material resources included purchases by the school, club activities to raise funds, support from the Future Scientists of America Foundation, and industrial support. Acquiring additional library materials through better utilization of the United States Patent Office, the College of St. Francis Library, the John Crerar Library in Chicago, and industrial libraries in the local area were discussed at length. In discussing the need for professional consultation, the Board carefully considered the type of persons needed, the individuals in the area who would be interest and available, and how their assistance might be secured.

Over a period of time, a plan evolved in which the Board of Directors selected a group of students interested in research. After the students were selected, the problems present in the students' projects and the Board of Directors' suggested solutions to these problems were presented to an industrial scientist. He accepted the plan with enthusiasm and immediately steps were taken to put it into operation.

SELECTION OF PARTICIPANTS

Superior senior members of the Association were invited to submit applications to participate in the group research program provided they were preparing for a career in science and were willing to use school time and evenings for consultation and investigation. Preliminary selection of 10 applicants was made by the Board of Directors and by H.

Neil Hardy, the Association's Sponsor.

Applicants were evaluated according to: interest in such a program; reasons for wanting to participate; interest in science as indicated by hobbies; previous science and mathematics courses studied; and work experiences. Other information, such as special achievements and honors, their agreement to give regularly of time in and out of school, and recommendations of employers and teachers were carefully weighed.

Final selection of six students and the arrangement of these into workable groups were made by Mr. Hardy. Final selection was based on students' plans for future scientific careers, interest in scientific endeavor, and ability to cooperate and work with others. The six participants were placed in teams of three. The club sponsor asked each of the participants to list in order of preference the three members of the group with whom they would most like to work. With this information and personality traits observed in school activities, assignments were made.

Industrial Consultant

The Board felt that the industrial consultant should have experience working with students, a genuine interest in students and teaching, a background in chemical research, experience as a leader or director of a research group, and time and help he could and would give in consultation.

The Board was unanimous in its approval of Dr. J. V. Karabinos as a consultant. As Director of Organic Research at Blockson Chemical Company, a division of Olin-Mathieson Chemical Corporation, he had given his assistance to the Association's activities on numerous occasions. Serving as Chairman of the Chemistry Section of the Illinois State Academy of Science, as a senior research consultant at the College of St. Francis, and a consultant for the production department of Olin-Mathieson Chemical Corporation provided him with a broad background for dealing with the diverse problems always present in student projects.

Dr. Karabinos entered into the plan with enthusiasm and was responsible to a large extent for the program's success.

Preliminary Planning

All Association members knew they were expected to complete and exhibit a project during the school year, and each team first concerned itself with a group problem rather than ones for individual students. The Association's sponsor discussed possible areas of investigation with the students and with Dr. Karabinos.

At the first session with the research consultant, the areas of interest were discussed and evaluated. Many new and important related ideas concerning scientific investigation were introduced to the students. Dr. Karabinos met with each group and gave participants an opportunity to ask questions and to express their current interests in investigation.

Within a week, each of the groups selected a tentative problem and began a literature search in the libraries at Lincoln-Way and College

Lee Yunker, a member of the Phi-Chem Association's research group at Lincoln-Way High School, questions Dr. Karabinos concerning the isolation of rare earths as Wayne Klasing and Bob Hughes look on.

of St. Francis. One team finally selected the isolation of the rare earths, and the other selected separation of substances by the use of detergent foam.

Consultation and Materials

A consultation meeting was arranged by the sponsor for Saturday morning, ten days after the first session. The groups met in the library of Blockson Chemical Company where, with the assistance of the librarian, they became acquainted with scientific journals and other sources of scientific information. Numerous scientists, who were working in the laboratory that morning and had an interest in the fields being investigated by the groups, stopped by the library to talk with the students and to give suggestions concerning sources of information and methods of proceeding.

After the library session, Dr. Karabinos met with each of the groups and discussed their current problems in relation to information, procedures, and materials. Blockson opened its library to the students and offered to secure photostats of any pertinent article in the literature. Dr. Karabinos provided adequate quantities of rare earth carbonates, rare earth oxides, and one type of ion exchange resin. He secured six different types of deter-

Charles Otto, James Landfried, and Burke Lanham, members of the Phi-Chem Association's research group at Lincoln-Way High School, confer with Dr. Karabinos concerning the separation of compounds by the use of detergent foam.

gents and prepared a glass column for the group working with the separation by the use of detergent foam.

The students frequently returned to the library at Blockson and consulted with Dr. Karabinos on Saturday mornings or over the telephone when problems developed. The group working with rare earths visited the Lindsay Chemical Division of the American Potash and Chemical Corporation at West Chicago to secure additional information on procedures. They were

given a quantity of rare earth sulfates and ethylenediaminetetraacetic acid to use as an eludent. Several scientists at the local Science Open House offered ideas and suggestions. One scientist from Armour and Company sent materials on mineral flotation to the group working on separation by detergent foam and arranged for them to meet and consult with the director of the Armour Research Laboratory in Chicago. This interest and assistance on the part of professional scientists added impetus to the student investigations.

Interpretations and Suggestions

Late in April, the group working with rare earths felt it had succeeded in separating seven of the individual elements and the group working with detergent foam and foam separation had some very interesting data. Problems of interpretation of data and technical procedures multiplied rapidly, and the student groups asked for a conference with Dr. Karabinos. He came to school to meet with them; he observed procedures, results obtained, and made suggestions concerning procedures and treatment of data.

The group working with the separation of rare earths had questions concerning the use of eludents, the relative use and value of various ion exchange resins, and procedures and methods for placing cations on the resin columns. Although they had several well-defined curves on their graph, they were not certain that they had actually separated the individual rare earths.

The investigation on foam had resulted in some very interesting data, but the interpretation was difficult. Samples of foam taken from the top of a column containing a mixture of detergent and water with air passing through contained varying amounts of detergent. In fact, a graph of their results approached a normal fractional distillation curve. Additional problems in the separation of compounds by foam were encountered when chemical reactions occurred between detergents and the materials being separated.

Following this evaluation and suggestion session, students returned to their investigations with zeal and enthusiasm; they saw new questions and new ways of finding the answers.

Reactions of Student Participants

Student enthusiasm for and interest in the program was high from the day it was announced. Charles Otto, President, and Mr. Hardy, Sponsor of the Association, were besieged from the time the first applications were received until the final selection of six participants was made. These six students allowed no one to rest until they had their consultation with Dr. Karabinos and their problems selected. Every day at least one of the six would inquire if the laboratory would be open for the students that evening or over the weekend, and whenever it was open, several members of the group were present and working. The participants' willingness, and even urgent desire, to spend extra time in the laboratory showed a great amount of interest.

The members of both teams were eager to discuss their work with students, scientists, and interested

adults. They asked to present reports at Phi-Chem Association meetings, and they prepared papers for presentation at the local conference symposium and at the state meeting of the Illinois Junior Academy of Science. Both teams exhibited their work at the local Open House, district and state meetings of the Illinois Junior Academy of Science, conference science symposium, and a local meeting of the Lions of Lincoln-Way. Probably the best indication of their interest was their willingness to take time at any hour of the day or evening to explain their work to visitors to the science department. This interest was certainly gratifying to the school administration, to the Board of Directors of Lincoln-Way Community High School, to the staff members, and to outside visitors.

Perhaps from a scientific point of view, the greater understanding they developed of scientists and the scientific approach was the most valuable result. They exhibited this new interest and understanding whenever they had an opportunity to visit with research scientists. Participants were eager to know what problems the scientist was working on, how he was collecting and treating his data. Certainly there was developed a greater appreciation of the methods of research.

This development in the participating students had related effects on the students in the science department and, to a limited extent, on the total school population.

Reactions of Science Students

The reactions of science students in the department indicated additional prestige for the department and the participants, and a better understanding of scientists and their work. Initial interest was shown by the large number of students who completed application forms. This initial interest continued throughout the project, as was amply shown by the students' attentive interest during progress reports in Association meetings and by the many individuals who stopped by the laboratory to check on the progress the groups were making. Students, in general, were interested in the visits of Dr. Karabinos and in hearing suggestions and criticisms which he made. Probably this interest was partly due to the prestige he gave the department by coming and spending half-days with the students.

Through the reports in Association meetings and individual observations, most of the science students at Lincoln-Way became better acquainted with scientific research, its problems, and its operations. They now have a better idea of the time consumed in research and a knowledge of the pleasure derived from securing significant results.

Reactions of Scientists

The student investigation plan was enthusiastically endorsed by all who came in contact with it. Dr. Karabinos was appreciative of the opportunity to work with the students, and from the first discussion of the idea through the investigation period, gave time and effort toward its success. Whenever students telephoned or visited Blockson, he gave them unlimited assistance. On other occasions, he telephoned the school

to inquire how they were progressing. His discussions with the Association's sponsor have indicated satisfaction with the success of the endeavor.

Judges and scientists at the annual Science Open House took special note of these exhibits and offered special assistance and suggestions. Several of these offers of assistance included time and money on the part of individual scientists. Their comments following the judging were enthusiastic, and they were eager to see this type of program increase in scope and number. During the state meeting, graduate students stopped to visit and returned later with their professors to show them the work that high-school students were doing. These visits resulted in several invitations to the laboratories on the Champaign-Urbana campus of the University of Illinois.

The sponsor has gained additional knowledge and has enjoyed working with the program. From a teacher's viewpoint, it was a pleasure to see student interest develop and increase throughout the investigations. The interest of students and adult visitors in the program was most gratifying. The sponsor would again help initiate and encourage a similar program.

Summary

A high-school research plan is discussed; an industrial specialist and a teacher cooperatively work with high-school students to guide their selection of a problem and to assist them in securing information and materials. The investigation adds prestige among the total school population, to the science department, and to the science students who participated. The participants and observers are enthusiastic about the plan and feel it could be used effectively in other situations.

Manuscript received September 7, 1959.

FILMS RECOMMENDED FOR INSTRUCTIONAL PURPOSES

MILTON D. THOMPSON, *Chairman*
Educational Films Evaluation Committee, Illinois State Academy of Science

1. ANIMALS—WAYS THEY MOVE (EB) 10 min., sound and color, three star[2], p-i-j.[1]

   A colorful and interesting demonstration of animal locomotion, including swimming, crawling, hopping, running, walking, climbing, flying, etc.

   Reviewer: M. D. Thompson.

2. ANIMALS—WAYS THEY EAT (EB) 11 min., sound and color, four star[2], p-i-j.[1]

   A very elementary and interesting study of the manner of feeding of higher vertebrates, especially birds and mammals. Shows diverse types as bills of birds, grinding teeth of cows, tearing teeth of lions, noses of pigs and elephants, and many others. Excellent close-up photography.

   Reviewer: M. D. Thompson.

The Audio-Visual Center at the University of Indiana is distributing three films on microorganisms. They are excellent for high-school biology and for hygiene and health education in college, but are felt to be too elementary for college bacteriology. The educational collaborators are: Walter A. Konetzka and Leland S. McClung. The films are:

3. BACTERIA—LABORATORY STUDY (U. Indiana) 15 min., sound and color, three star[2], h-c′.

   Deals with bacteriological procedures such as sterilizing, culturing, staining, and examinations. Suggests some techniques for examination.

   Reviewers: M. D. Thompson and J. M. Sanders.

4. MICRO-ORGANISMS — HARMFUL ACTIVITIES (U. Indiana), 15 min., sound and color, three star[2], h-c′.

   Deals with diseases of people, plants, animals, and with food spoilage. It points out such factors as refrigeration, food preservation, public health measures, and community health with references to viruses, toxins, antitoxins, general immunity, phagocytosis, antibodies, and Koch's postulates. The film may create some wrong impressions concerning such diverse subjects as tuberculosis and chemical food preservatives due to over simplification.

   Reviewers: M. D. Thompson and J. M. Sanders.

5. MICRO-ORGANISIMS — BENEFICIAL ACTIVITIES (U. Indiana), 15 min., sound and color, three star[2], j-h-c.[1]

   Designed primarily for those who have not had a background of micro-biology, it presents quite simply, but effectively, subjects such as decay, enzymes, metabolism, the nitrogen cycle, antibiotics, yeasts, alcohol, acetic acid, silage, and the carbon cycle.

   Reviewers: M. D. Thompson and J. M. Sanders.

6. BASIC NATURE OF SEXUAL REPRODUCTION (U. Indiana), 15 min., sound and color, four star[2], h-c'.

A classroom film of quality, illustrating the similarity of sexual reproduction in plants and animals, both as to the nature of gametes (size, shape, mobility difference, as between male and female), and the sex organs of plants. In animals, ascaris slides are used to show fertilization, and meiosis is shown by models and movable chromosomes. The film seems better suited to the study of plant morphology than to genetics. Diction of the narrator is not always clear, and a knowledge of the terminology is assumed.

Reviewers: M. D. Thompson, J. M. Sanders, and Elnore Stoldt.

7. CHAMELEON (International Film Bureau), 6 min., sound and color, three star[2], i-j-c-a.[1]

Prepared under supervision of New York Zoological Society. Elementary but extremely interesting. Demonstrates color adaptability and suggests some of the factors that effect it, such as light, heat, and emotions. Illustrates how chameleons climb and walk, peculiar foot adaptation, prehensile tail, independent eye movements, and the use of the tongue in capturing insect food.

Reviewer: M. D. Thompson.

8. CHANGING CLIMATES (Pictura), 11 min., sound and color, three star[2], i-j-h.[1]

A striking film on Alaskan glaciation. Shows how something of the climates of the past can be interpreted from a study of glaciers and their work. Elementary, nontechnical science.

Reviewers: M. D. Thompson and C. Condit.

9. CRUSTACEANS (EB), 15 min., sound and color, three star[2], j-h-c-a.[1]

Interesting colorful film on lobsters, barnacles, shrimps, and their relatives. Carefully prepared text, excellent photography, good selection of representative groups, and a high interest level.

Reviewers: M. D. Thompson and P. W. Parmalee.

10. ERUPTION OF KILAUEA (U. S. Geol. Survey), 11 min., sound and color, three star[2], j-h-c-a-Aud.

Documentary film of the 1955 eruption of Kilauea. For the first time in Hawaii, and probably anywhere, scientists were able to observe and photograph at close range the entire sequence of the development of volcanic events. Having been warned by hundreds of earthquakes, the photographers were able to cover the eruption from the first opening of fissures in the ground, appearance of lava, formation of cones, and flows, firework displays of lava fountains and great pillars of billowing steam as a lava river reaches the sea. Recorded by volcanologist Gordon A. MacDonald, Director of the U.S.G.S. Hawaiian Volcano Observatory, as a scientific record. It is not in

the usual educational film format. The vocabulary in places is somewhat technical.

Reviewers: M. D. Thompson and C. Condit.

11. EXPLORING RY SATELLITE (Delta Film Productions, Inc.), 28 min., sound and color, four star[2], j-h-c-a.
Most interesting and informative. Interesting and detailed information on the Explorer Satellite, showing its fabrication, instrumentation, assembly, manner in which it records and transmits data back to earth and tabulation of data. Shows with considerable detail the assembly of the rocket mechanism, fueling, firing, and tracking. Achieves drama and suspense.

Reviewers: M. D. Thompson and C. Condit.

[1] Recommended for: p—primary; i—intermediate; j—junior high; h—high school; c—college; a—adult; Aud.—Auditorium.

[2] Very best films (one or two per year) are rated as five-star films. A three-star film is good, accurate and suitable but does not have the outstanding features, interest and technique of the best films.

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1959-1960

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ADVISOR TO STUDENT OFFICERS: Miss Ica Marks, Eastern Illinois University, Charleston.

PAPER SESSION: William P. Cote, Bremen High School, Midlothian.

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PIN SALES: A. J. Hoffman, Eastern Illinois University, Charleston.

FILMSTRIP: John C. Chiddix, Normal Community High School, Normal.

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EXHIBITS ASSISTANT & AWARDS CHAIRMAN: William L. Downes, University Illinois, Urbana.

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BANQUET: Zane B. Carothers, University Illinois, Urbana.

WESTINGHOUSE TALENT SEARCH: L. R. Heckard, University Illinois, Urbana.

Judging Division Chairmen

AERONAUTICS: Alfred F. Stott, 4044 Woodland Ave., Western Springs.

ANTHROPOLOGY and/or ARCHAEOLOGY: Elaine Bluhm, 137 Davenport Hall, University Illinois, Urbana.

ASTRONOMY: R. P. VanZandt, 1100 N. Parkside Drive, Peoria.

BOTANY: Miss Alene Ruyle, Carlinville High School, Carlinville.

CHEMISTRY: Vaughn Armer, Oak Park-River Forest High School, Oak Park.

CLUB ACTIVITIES: Milton D. Thompson. Illinois State Museum, Springfield.

CONSERVATION: Robert L. Smith, DeKalb High School, DeKalb.

GEOLOGY and/or GEOGRAPHY: Roger Brown, University High School, Urbana.

MATHEMATICS: Sister Crescentia, College of St. Francis, Joliet.

METEOROLOGY: Glen E. Stout, American Meteorological Society, 101 Elmwood Road, Champaign.

PHOTOGRAPHY: John Ronketto, Jr., Canton Sr. High School, Canton.

PHYSICS: Charles Foreman, Maine Township High School, Park Ridge.

RADIO: V. F. Hershey, Illinois Bell Telephone Co., 625 S. 6th St., Springfield.

ZOOLOGY: Thomas Wilson, Evanston Township High School, 1600 Dodge, Evanston.

District Chairmen and District Meetings

NORTH SUBURBAN:

Steve Kubisen, Glenbrook High School, Northbrook.
Guenther Kolb, Evanston High School, Evanston.
April 9—Evanston High School

SOUTH SUBURBAN:

Donald Hopkins, Carl Sandburg High School, Orland Park.
Joe Gross, J. Sterling Morton High School, Cicero.
Henry Krass, Downers Grove High School, Downers Grove.
April 9—Illinois Institute of Technology

NORTHERN:

Kenneth Harmet, Northern Illinois University, DeKalb.
Herbert Tischler, Northern Illinois University, DeKalb.
Edwin Shykind, Northern Illinois University, DeKalb.
April 2—Northern Illinois University

NORTHWESTERN:

John Ronketto, Jr., Canton Sr. High School, Canton.
Bill Vasen, Canton Jr. High School, Canton.
Maurice Kellogg, Western Illinois University, Macomb.
William Crall, Western Illinois University, Macomb.
Herbert Priestley, Knox College, Galesburg.
April 9—Canton Senior High School

CENTRAL:

Harvy Jackson, Illinois State Normal University, Normal.
Tom Edwards, Illinois State Normal University, Normal.
Kermit Laidig, Illinois State Normal University, Normal.
April 9—Illinois State Normal University

SOUTHWESTERN:

Felix H. Lauter, Illinois College, Jacksonville.
April 9—Illinois College

SOUTHEASTERN:

Miss Ica Marks, Eastern Illinois University, Charleston.
A. J. Hoffman, Eastern Illinois University, Charleston.
April 23—Eastern Illinois University

SOUTHERN:

Willard M. Gersbacher, Southern Illinois University, Carbondale.
Otto Ohmart, Anna Jonesboro High School, Anna.
Miss June Balding, Nashville Community High School, Nashville.
April 2—Southern Illinois University

CHICAGO PUBLIC SCHOOLS:

Edward Schwachtgen, Bureau of Curriculum Development, 228 N. La Salle St., Chicago.
April 7-10—Museum of Science and Industry.

CHICAGO AREA CATHOLIC:

Sister Mary Ivo, Immaculata High School, 640 Irving Park Road, Chicago.
Brother Stoehr, St. Leo High School, 901 W. 79th St., Chicago.
April 23—DePaul University

STATE MEETING:

May 6 and 7, 1960, University of Illinois, Urbana.

THE EDITOR'S PASSPORT

"The Editor stood 'fore the Heavenly Gate,
His features pinched and cold.

He bowed before the Man of Fate,
Seeking admission to the fold.

'What have you done?' St. Peter asked,
'To gain admission here?'

'I was the Journal's editor, Sir,
For many a weary year.'

The Pearly Gates swung open wide
As Peter pressed the bell.

'Come in and choose your harp,' he cried;
'You've had your share of Hell!'"

Journal of the Irish Medical Association

EDITORIAL NOTE

It would be impossible to thank all those who have aided me in the editing of the *Transactions* during the last five years. I am especially grateful to the members of the Editorial Board and others who have helped evaluate manuscripts submitted. Particular credit should go to the authors for their patient understanding of the necessities of financial and chronological factors.

Many changes have been made in the *Transactions*. I hope the majority were improvements.

I should like to ask that the cooperation received by me be extended to the new editor, Dr. Paul Silva, Department of Botany, University of Illinois, Urbana.

HARVEY I. FISHER

PREPARATION OF MANUSCRIPTS FOR THE TRANSACTIONS

For publication in the *Transactions*, articles must present significant material that has not been published elsewhere. Review articles are excepted from this provision, as are brief quotations necessary to consider new material or varying concepts. All manuscripts must be typewritten, double spaced, with at least one-inch margins. The original copy, not the carbon copy, is to be submitted.

Titles should be brief and informative. The address or institutional connection of the author appears just below the author's name. Subtitles or center headings should be used; ordinarily one uses subtitles such as *Introduction*, *Acknowledgments*, *Materials*, *Methods*, *Results*, *Discussion*, *Summary*, and *Literature Cited*. All papers should have a summary.

No footnotes are to be used.

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